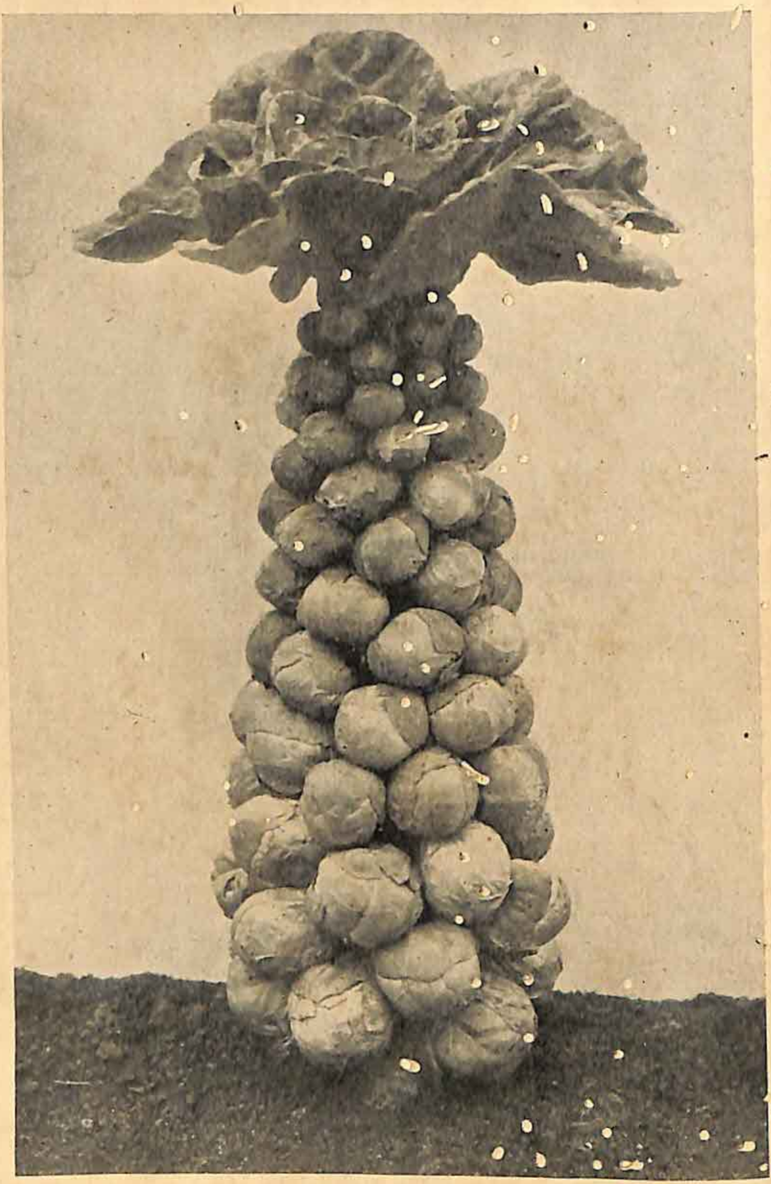
1021

SCIENCE IN THE SCHOOL GARDEN

MARY A. JOHNSTONE

635
Joh



Sutton & Sons, Ltd.

BRUSSELS SPROUTS

A very perfect form of this member of the cabbage family. Why not aim at it?

SCIENCE IN
THE SCHOOL GARDEN

By

MARY A. JOHNSTONE
B.Sc., F.L.S.

Formerly Head Mistress,
Manchester Central High School for Girls

INSTITUTE OF EDUCATION FOR WOMEN
1021
Dept. of Extension
SERVICE.
★ CALCUTTA-27 ★

635
Joh

LONDON
MACMILLAN & CO. LTD
1951

This book is copyright in all countries which are signatories to the Berne Convention

PRINTED IN GREAT BRITAIN

PREFACE

THIS BOOK has been written expressly for primary schools and the lower forms of secondary schools, in particular in the former case, with the view of its being used in the two years previous to leaving school. It does not presuppose the existence of the equipment required for a course in school chemistry, or the presence on the staff of a teacher having the orthodox training in chemistry, though there is a chemistry of the things and events of common life which may be assumed to be within the knowledge of most teachers. If a course in elementary chemistry is followed in any school which uses the book, it will be natural for the teachers concerned to carry out a much wider range of chemical experiments than are indicated in these pages; the teachers can be left to choose and direct these for themselves.

Quite apart from the question of facilities, my aim is not to emphasize chemistry, but to introduce the children to the science of living things, of growth and what it depends upon, always recognizing the interdependence of plant, animal and inanimate Nature. The object aimed at as being of the most vital importance has been the cultivation of a scientific habit of mind, a possession which ought to be of life-long service to the owner of it. It is the habit of mind which is continually enquiring, never satisfied until matters under discussion have been proved; it can apply itself to all branches of mental activity—history, science, everyday life. It is the experimental mind, which tries to find out the truth for itself, which exercises the extremity of care over accurate detail, which is prepared to be patient and persevering, to face failures with reduplicated efforts. In its own simple fashion, the school garden may function as a research laboratory, giving to the expression its essential meaning—a place where truth is sought after.

The garden is a place, too, which encourages co-operative activity, a place for the interchange of opinions. It has not been my purpose to produce a manual of gardening practice in its many details; it is assumed that the school will have a teacher who is a master of this craft. It is written for the pupils, not the teacher; it should be a book of reference which they possess individually, to be used again and again as occasion arises. For class purposes, the chapters may be taken in any order which suits the school curriculum and the weather.

A school garden which is everything that such a garden should not be presents itself to critical eyes in a certain village. The soil is recognized as being very poor, a fact which ought to give scope for experimental attempts to improve it and to find out what type of plant it can be made to grow as a satisfactory crop. No attempt whatever is made to cope with the unfavourable conditions; regulation digging and planting are carried out and nothing more. Results are miserable; nobody seems interested in the place; this considerable piece of ground is an unhappy-looking spot. What do the parents in the village, who cultivate their little plots with success, think of such a venture? They regard it as a waste of labour, time, and public money. Further, entirely wrong lessons in garden procedure are being taught there, and no such garden would encourage a young worker to carry his labours forward into the future.

The book has been produced under the editorship of Mr. L. J. F. Brimble, to whom I offer my warmest thanks for the friendly cordiality of his supervision, and for his wise guidance on many matters, including illustrations.

I also wish to express my indebtedness to the Editor of the *School Science Review*, for allowing the reproduction of the experiment detailed in Chapter X; likewise to Messrs. Dent for the use of line drawings from my "Matriculation Botany", published by them.

M. A. JOHNSTONE

Hindhead, Surrey,
May 1951

CONTENTS

CHAPTER PAGE

PREFACE vii

I. INTRODUCTION 1

II. GENERAL STRUCTURE OF A PLANT . 3

III. THE INSECT AND THE FLOWER . . 16

IV. THE HONEY BEE 23

V. THE SOIL OF THE GARDEN . . 36

VI. THE TEMPERATURE OF THE SOIL . 49

VII. THE PEOPLES OF THE SOIL . . 55

VIII. DIG FOR FOOD 64

IX. WE FEED THE SOIL. . . . 68

X. WATER-CULTURE EXPERIMENT . . 79

XI. REARING SEEDLINGS . . . 91

XII. WHAT SHOULD YOU GROW? . . 99

XIII. POTATOES 105

XIV. LEGUMINOUS PLANTS . . . 117

XV. THE CABBAGE FAMILY AND OTHERS . 127

XVI. THE GARDENER AND THE WEATHER . 141

XVII. ODDS AND ENDS 148

CONCLUSION 167

APPENDIX OF ADDITIONAL EXPERIMENTS . 169

INDEX 173

ILLUSTRATIONS

Brussels Sprouts . . . . . *Frontispiece*

FIGURE PAGE

1. How water is absorbed by root-hairs . . . 4
2. Diagram showing plants growing together in woodland 7
3. Diagram showing the path followed by water within a plant 9
4. Stomata 10
5. Diagram showing parts of a flower . . . 14
6. Fertilization 19
7. Bee-hives in an apple orchard in Kent . . . 21
8. Honey bee 24
9. Honey bee; head of worker 25
10. Hind leg of honey bee 26
11. Proboscis of a moth 34
12. Biting mouth of a beetle 35
13. Wireworm 57
14. Bacteria 59
15. Diagram of glass stopper 81
16. Three stages in the growth of a seedling of a broad bean 93
17. How leaves emerge in the lesser celandine . 97
18. Jerusalem artichoke 106
19. Virus disease (leaf-drop streak) of potato . 112
20. How a sap-sucking insect feeds . . . 113

FIGURE PAGE
21. Stylets of an aphis carrier of a virus disease entering a potato leaf 114
22. Colorado beetle 115
23. Scarlet runner bean showing twining stem . 119
24. Pea and bean weevil 122
25. Root system of broad bean 123
26. Snail's head 129
27. Cabbage moth 130
28. Carrot fly 133
29. Bluebell plant 138
30. Germination of onion 140
31. Crocus corm 156
32. Spraying crops with D.D.T. from a helicopter 159

CHAPTER I

INTRODUCTION

I WISH I could talk face to face with you boys and girls who are about to start work in your school garden. It is possible to make work in your school garden quite dull and mechanical; but you can, on the other hand, think about it in such a way that you become filled with wonder and admiration over the sure and secret ways pursued by the living things which you cultivate.

Turn over in your mind some of the little seeds which you will one day hide away in the soil of your garden; think of what their future may be, though they look so insignificant, and I think you will marvel over them. Within these morsels is stored away the power *to grow*; within them dwells *life*, which is the most heavily shrouded mystery in the universe—a mystery which no one has yet fathomed. They are not as the grains of sand in which is found no breath of life.

A friend of mine who loves to watch the changes taking place in young green plants calls them 'the little miracles of spring-time'. Just ponder over these miracles as you see them taking shape from day to day. The whole aim of gardening is to give them a chance to run their course. You are to have the privilege of helping life to develop to its full extent; you may be a miracle-helper.

I have watched the tiny spear-points of the plant called the lesser celandine as they peered out from the soil, pushing it aside gently but with patient determination, seeming to know exactly which direction was the best for them to take. I have also gazed long and often into the depths of a forest of thick-planted trees growing on an Italian mountain-side—trees hundreds of years old. Unerringly, they each and all struck straight upwards towards the sky. A mighty force of some kind had directed them and refused to be thwarted. It was the same compelling force as had guided my mites of celandines. The stem *must* grow upwards, the first root which feeds it *must* go downwards. Why? Can you answer that with certainty? Who can?

You place your little seed in its bed, and soon you find out that this law of growth governs it. Think about this problem and about the many others which will offer themselves to you as your work proceeds. Perhaps if you continue to study them you will find answers to some which no one yet has solved. It means, though, that you must be persevering; must never be discouraged by failures; must frequently just try again.

CHAPTER II

GENERAL STRUCTURE OF A PLANT

IN YOUR gardening you will aim at directing the life of a plant so that it may grow to the fullest perfection. That the gardener may be able to do this intelligently he ought to know the essential facts about the structure of an ordinary plant, and how it feeds itself when it is left to do so by its own efforts. If you could have a simple course in botany along with your gardening it would help you, but in case you cannot I will give you here a very short description of the principal parts of a flowering plant.

You must follow it point by point with an examination of some plant or other which is available. A wallflower plant is suitable, so are broad bean, foxglove and others. They must be examined at different stages in their existence.

Take up a young wallflower plant carefully from the soil. For preference, you should dig the plant, not pull it, else you break the roots. Rinse its roots slightly under the tap, but do not try to rub off the clinging soil. You find that there is present a central axis with side growths. Let us deal with the underground part of the axis first. It forms the main root and grows directly downwards. The side roots run obliquely downwards and in some plants branch several times. The tips of the smallest roots are the parts of most importance. If you set up the following little culture experiment you will get a clear idea of them.

Fit up a wide-mouthed bottle with a cork and partly fill it with water. To the under surface of the cork pin a broad bean seed which has been soaked for about twenty-four hours in water, and leave it to germinate in the moist air above the water. You will find that the little roots become clothed, throughout part of their length—near, but not quite up to the tip—with a delicate fluff of hairs. Most plants depend on these fine hairs for their existence, and you must pay great attention to them. The botanist speaks of them as **root-hairs** (Fig. 1). They are excessively thin and soft, as they ought to be, because they serve as the entrances through

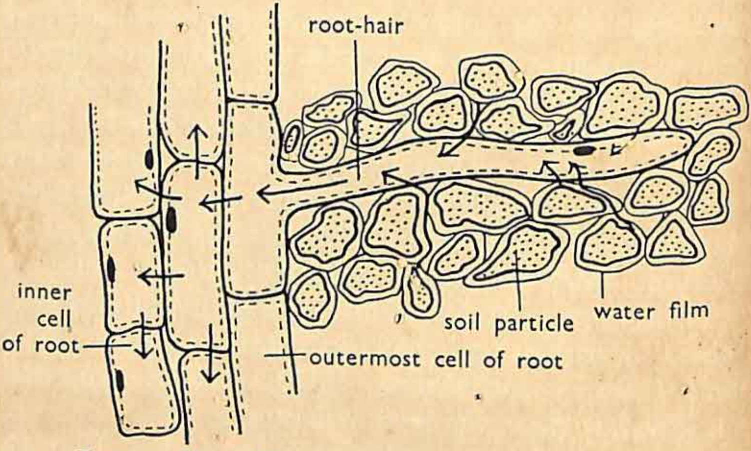


FIG. 1. HOW WATER IS ABSORBED BY ROOT-HAIRS
Arrows show direction in which water travels.

which water and the substances dissolved in it penetrate into the plant. Do not imagine that the water which falls on leaves passes right through their skins, except in very rare cases. Mineral food must all be dissolved in water before the plant can take it in by these root-hairs, which thus serve as mouths. The way in which the root-hairs act will be explained later (p. 42).

These facts must be used as guides in some of your work in the garden. When you are transplanting plants, particularly seedlings, you must take the greatest care not to injure the small roots and the root-hairs by rough handling; above all you must not leave them exposed to the air for even a few minutes, lest they should get dried up. If destroyed, it takes some time for others to grow, and meanwhile the plant is losing water from its leaves; it will wilt, and suffer a check in growth. When removing a plant use an implement which will lift a goodly ball of soil having the roots embedded in it; place this in its new position without disturbing it.

You will notice how the absorbing tips of the side roots of the wallflower spread out to some distance from the central root; this varies in different plants. In a number of plants the central root becomes quite unimportant. This you must remember when you are supplying extra food or extra water to older plants. Try to place what you are applying exactly where it will be most useful. Sometimes the food is in the form of a powder; it must be worked into the soil at some little distance from the stem. You have to find out by experience just how far outwards each kind of plant spreads its roots. Fruit bushes have, or ought to have, roots which keep fairly near the surface and travel outwards; this tells you that when you are spreading manure or a mulch round them you look out for the root tip region. If you want to see an extreme case of root-spread, watch out for a big tree like a spruce which the wind has overturned. You will be surprised to see that the roots may be spread through a sheet of soil yards wide but probably not more than a foot in depth. The active rootlets are mostly at the outward edge of the circular sheet, and get their water from the streams shed off by the conical arrangement of the branches of the tree.

In some plants the roots are short and crowded together in a bunch. When you are choosing plants for any particular piece of ground you have to take into account their special type of root—short or long. Do not, for example, put short-rooted plants into ground in which the feeding stuff is too deep for them to reach it. In Nature, some plants have found that they can thrive when packed very close together if this rule is observed, so to speak. You may find, growing together in a wood, the following —soft green grass rooted in the top layers, bracken rooted in those just a little lower, and wild hyacinth bulbs below that again. They are feeding in different fields or layers, as it were, placed one above the other. (Compare with Fig. 2.)

In the whole course of your gardening pay close attention to the roots of the plants you grow; not only make notes of their character in every kind of

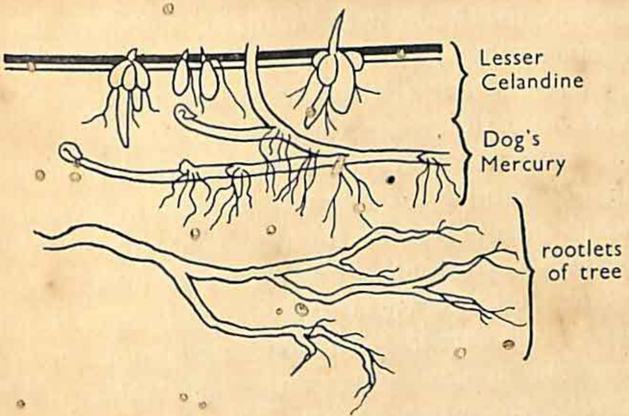


FIG. 2. DIAGRAM SHOWING PLANTS GROWING TOGETHER IN WOODLAND
Roots at different levels.

plant, but also be on the look-out for diseased roots. An unhappy condition of the parts of the plant above ground, for example, yellowing leaves, stunted growth, should make you suspect that all is not well below ground. As you will learn by-and-by, the ground teems with enemies of the roots. Your carrots are failing, and examination shows that small maggots are eating into their substance; the carrot fly has got at them (p. 132). Cabbages stop growing, and their roots are found to be swollen, knotted and unsightly; this means that they are infested with a lowly fungus, which sets up this 'club-root', or 'finger-and-toe' condition. The fungus lives in the soil, and is difficult to get rid of; repeated liming helps to check it. Examine the root system of a healthy pea or bean plant. It ought to be covered with numerous small warts. Certain bacteria are responsible for the growth of these, and they are of enormous service to the plant. The absence of these bacteria from that particular bit of ground would be most unfortunate for the crop (p. 122).

We now pass on to consider that part of a plant which exists above the ground. The main **shoot** is the upward continuation of the first root, and gives off branches which usually grow outwards and upwards at varying angles. **Leaves** are spaced on these in regular order. New **branches** and **flowering** shoots arise as buds in the angles between the leaf-stalks and the stem from which they spring. The stem may remain soft and herbaceous, or it may become woody. Prominent on the under surface of the leaf is a network of **veins**.

If your school possesses a microscope it will be easier for you to get a correct idea of the wonderful system for carrying water which makes sure that every part of a plant gets what it requires. The water which is induced to enter by the minute root-hairs travels through long lines of water-pipes composed of short tubes joined end to end. First it runs into the smallest of the roots, then into the main root or roots; from these upwards into the main stem, along branch after branch; then, by way of the veins, into every corner of every leaf (Fig. 3). Flowing constantly through the meshwork of veins, it supplies all the green factories of the leaf tissue where food is being manufactured (p. 13). The stream, when matters are going properly, never dries up; when we see a plant wilting we know that the stream is failing for the time being.

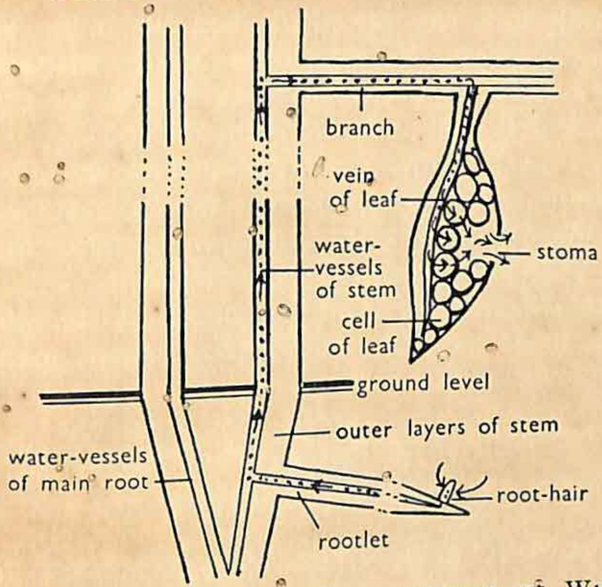


FIG. 3. DIAGRAM SHOWING PATH FOLLOWED BY WATER WITHIN A PLANT
(Proportions completely altered.)

The 'stock' of an old plant of the cabbage family offers you some very clear information about the little vessels which carry water all over the plant; the great soft leaves of a cabbage require a great deal of this. I happened to examine in April a plant of sprouting broccoli which had finished its career but still bore leaves at the top. The whole of the bare stem was close-set with little lozenge-shaped areas circling round it. Within each of them were placed five or seven dots, tiny pits, the central one placed a little lower than the others. When one of the leaves was gently parted from the stem it was seen that fine strands of material extended from the leaf-stalk and had fitted into the pits in the stem. The areas were really the scars left by lost leaves, and the pits marked the places where groups of water-vessels had left the stem to pass out to the leaf to form its veins, the lowest forming the mid-rib.

You may ask if the plant does not get over-gorged with this stream of water constantly pouring into it. This is guarded against very efficiently. On the under surface of the leaf, as is shown by the microscope, there are scattered numerous small openings

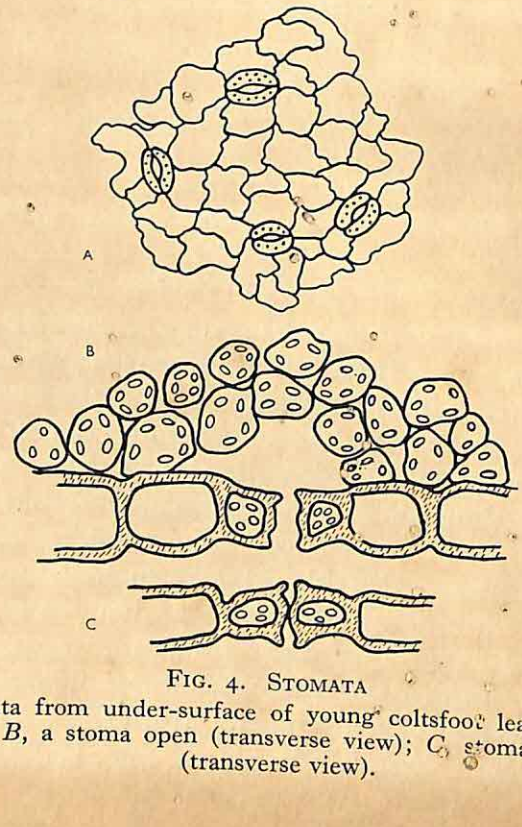


FIG. 4. STOMATA

A, stomata from under-surface of young coltsfoot leaf (surface view); *B*, a stoma open (transverse view); *C*, stoma closed (transverse view).

through which surplus water is got rid of in the form of vapour. The openings are known as **stomata** (one is a **stoma**) (Fig. 4), and the process is called **transpiration.** These facts are all important and worth remembering.

It is possible to gain a general idea of the course followed by the water-stream in the following way. Fill a vessel with water coloured with eosin or even red ink. In it place a specimen or specimens of such plants as a one-year-old wallflower shoot, a large soft bud like a Brussels sprout, a branch of garden nasturtium, or a white narcissus flower. The colour will be found to spread through the tissues in lines; sometimes it does so quickly, sometimes it is a day or two before effects are noticeable. If the plants are cut lengthwise as well as across, the paths taken by the water may be traced. A microscope will, of course, make things much clearer.

A little more must be said about the green leaves. The fact that they are green is their most important character; otherwise they could not do their work. The green colouring matter in the leaves is called **chlorophyll.** For its formation light is necessary. The garden will provide you with many examples of what happens to parts which should be green, when they are deprived of light. The leaves in the heart of a hard cabbage are pale yellow; the gardener blanches his celery by covering it up; potatoes sprouted in darkness have pale yellow leaves.

Day by day the plant grows larger and larger, and this must mean that it is continually making new substance for its body, of various kinds. For example, our own sugar supplies come from plants, as also does olive oil; so does the starch of potatoes and rice. The plant must make all these. On analysing them, the chemist finds that they consist of carbon, hydrogen and oxygen. Some, such as sugars and starch are called **carbohydrates**; others, such as olive oil, are called **fats.** When the chemist tests peas and beans he finds something different, for in addition to the three elements present in carbohydrates and fats they also contain nitrogen. He calls the new substance a **protein.** In a later chapter you will learn that the plant needs more to feed it than these four elements; but for the present we will think of these four only.

The sugars and all the rest of them have to be manufactured, which of course means work, and this again demands energy or power. The green leaves represent the plant factories. All the raw materials required for the building up of the plant substances can be got from the soil, with the exception of the bulk of the carbon. Strange as it may seem, this black solid with which you are familiar in coal has to be got from the air. Whilst man's factories employ water-power, steam or electricity the plant factory draws its energy from the sunlight which penetrates into its cells. Within these the task of capturing part of the sun's rays is allotted to the minute specks of green chlorophyll.

Try to picture what the interior of the leaf looks like. When magnified by the microscope it is shown to be a mass of hundreds of small portions of cell-matter which have each an independent existence. The botanist calls them **cells.** You may think of each one of them as being used like a room in a factory, if you like. They are more or less separated by spaces, and the veins wander about among them. To them must be brought the raw material for manufacturing the plant's goods. The veins bring to them from the roots water containing many substances in solution. The long spaces are like corridors all leading at last to the doorways which we saw were called stomata. So air can move about freely through the leaf and be taken in by the cells. Here is the chance for getting carbon. But you see nothing like carbon in the air. You may know, however, that air contains a gas called **carbon dioxide,** part of which the name tells us is carbon. If this can be broken up, the plant may get its carbon. This actually happens. The energy of the sunshine is enlisted to do the job, and the carbon is set free. Having got all it requires from water and the air, and still having the sun to help it, the plant goes ahead with its manufacturing. The gardener's share in the work is to see that the soil is fed, and to arrange for light and air to be available in abundance. He must also watch those precious leaves, and ward off the many enemies which try to feast on them.

Air is required by the plant for another purpose. You yourself are taking oxygen from the air into your body with every breath you draw. The plant is just as dependent on oxygen. The stomata of the leaves are the breathing pores by which it enters.

The next part of the plant to be studied is the **flower.** Its principal parts are four in number, arranged one within the other as circles, and seated on a small platform (Fig. 5). The outermost row is the **calyx,** usually green and numbering several **sepals.** Next to this comes a ring (or more than one)

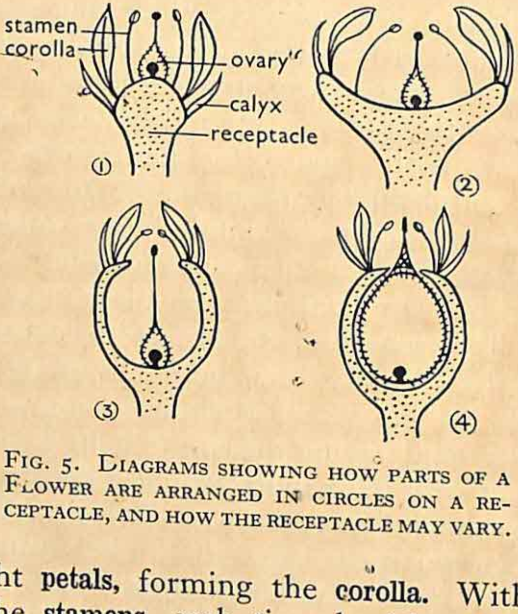


FIG. 5. DIAGRAMS SHOWING HOW PARTS OF A FLOWER ARE ARRANGED IN CIRCLES ON A RECEPTACLE, AND HOW THE RECEPTACLE MAY VARY.

of bright **petals,** forming the **corolla.** Within this stand the **stamens,** each tipped with a small case called the **anther,** filled, when ripe, with fine dust called **pollen.** Last of all, in the centre is situated the **ovary** or ovaries, within which lie the **ovules.** The ovary is drawn out into a **style** which carries a swollen tip called the **stigma.** The stigma is very important for it is planned for the reception of pollen. When pollen, which is the male element of the flower, is applied to the stigma, **pollination** is said to be accomplished, and **fertilization** ought to be the result of it. The ovule then becomes a seed, and the ovary ripens into a fruit. That is the outline of what occurs; your teacher will give you fuller details, and we shall have to consider it later on. There is infinite variety in the number, shape, colour and arrangements of the various parts of a flower, and you must examine some examples.

CHAPTER III

THE INSECT AND THE FLOWER

I REMEMBER the home-garden in which I spent many hours when I was young as being a place not only where good potatoes and good gooseberries grew but also as a place full of bright-faced flowers and the hum of contented bees. I had my own small domain in that garden where I was at liberty to make flower-patterns and try experiments.

Is your school garden a flower-garden, at least in part? It ought to be so, not only because it is well to work surrounded by the beauty of plants and the busy sounds of insect life, but because a school garden should be the scene of experiments and lessons taught by the lives of plants from their start to their finish. For these purposes you must have flowers to observe; especially must you have means of finding out how the flower and the insect serve each other. Your school garden should be far more important than just a bit of ground which produces things to eat. It can be made a kind of school laboratory for solving scientific problems, which means what is known as *research*. Even if food is the final aim, that cannot be achieved well unless it is done with an understanding of the whole life of the plant.

Hoping that you will have opportunities of going from flower to flower, in some garden or other, and testing the truth of what I say, I will try now to describe for you the vital events in the life of a flower, and also how flower and insect may become partners in making them successful.

You will remember the four circles of structures of which a flower is composed; the stamens and ovaries are those which are absolutely necessary. Compare a number of flowers in order to find out how much they vary. In your garden there should grow plants specially selected for the study of their flowering and seeding. You will find the flower of the broad bean a very convenient one with which to make a start, although the irregular shape of the blossom may confuse you at first. Compare it with a flower of regular shape like buttercup or wall-flower.

The green cup at the base, the calyx, is formed in the broad bean by the union of five sepals. The corolla, the next in order, consists of five irregularly shaped petals; one of them stands up as if demanding attention. Their peculiarities of shape and placing I have not space to enter upon here; so see what you can find out about them. Within the corolla are arranged ten stamens, partly joined together. In the centre of all lies a small body shaped like a miniature bean-pod; this is the ovary, and within it you can distinguish a number of little ovules. The tip of the ovary is prolonged, and swells out at the end into the stigma, which is finished off with a tuft of hairs. Probably a little sweet liquid, **nectar**, will have collected at the bottom of the cup. Examine the stamens, and you will find that the tiny cases are packed full of yellow dust-like pollen.

There is a process which *must* take place if a new life is to be started in any plant. I will describe it in a general way; you and your teacher will be able to discuss the details. First, you have the pollen grains lying in the anther cases, and the ovules in the ovary. The former are the male parts of the flower, and the latter the female. A grain of pollen must be brought into such a position that part of it can penetrate into an ovule and there unite with part of the substance of the ovule. When this union is accomplished *the act of fertilization is finished*. The ovule may now develop into a seed; that seed contains the germ, the **embryo,** of a new plant. So a new generation is given a start. Thus it goes on from generation to generation. The ovary with its seeds develops into the fruit.

The means by which the pollen is conveyed from the anthers to the ovaries differs vastly in different flowers. Watch what happens to the broad bean in the garden. If you are patient enough you may see a bee come along, investigate the flower, and sit down on the folded wing-like petals which might well be a platform expressly provided for it. It is seeking the nectar which it knows by its sense of smell, and by experience, is concealed within those petals. The petals are so cunningly fitted together that the pollen masses which have escaped from their cases are brought into contact with the hairy body of the bee. The petals give way under the insect's weight; the stamens and stigma shoot up so that its body gets nicely dusted over. Having got its drink, off goes the bee to another bean flower and repeats the performance.

Perhaps one of the flowers on which it lands has its stigmatic tip in a moist, sticky condition, which is a sign that it is ready to make use of pollen. Some of the bee's load sticks to the hairs of the stigma; then the work is practically done. We say that *pollination has taken place.*

If matters go well, the pollen grain begins to grow larger, and a thin tube pushes out from it and makes its way into the ovary (Fig. 6). Down the walls it travels till it can find an ovule. Into this it makes its way through a small hole planned for its convenience. A microscopic morsel of the tube-contents

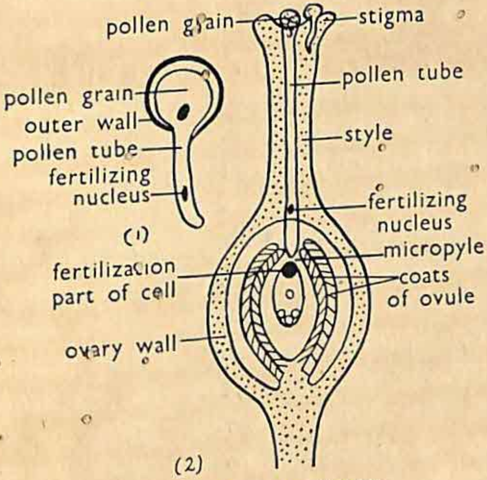


FIG. 6. FERTILIZATION

1, Growing pollen grain; 2, diagram showing how the pollen-tube grows down into the ovary of the flower.

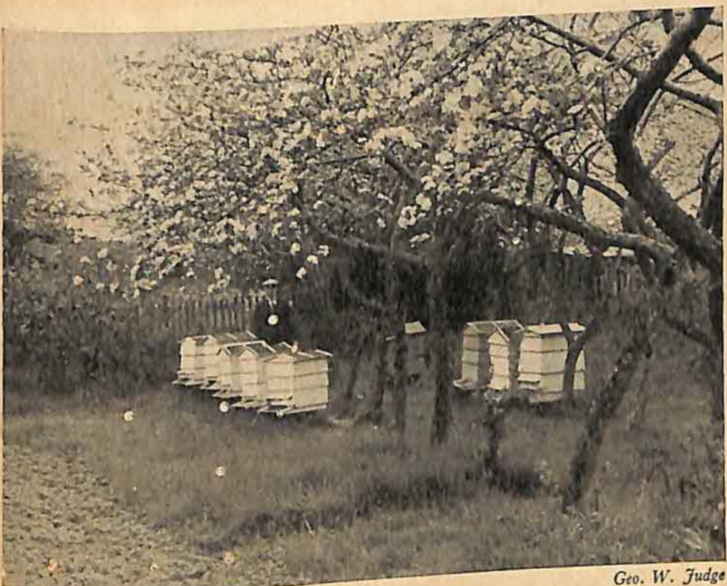
slips inside and fuses with an equally minute bit of the body of the ovule (Fig. 6). Now the great deed for which the plant exists is done. *The union of the two parts constitutes the act of fertilization, through which is created a new individual life.*

In the case of the bean, it was the bee which transferred the pollen to its place of action. In some plants, the agent is the wind. You know how the pollen of grasses, for example, floats about in the wind; some of it may chance to alight on stigmas; but this is a wasteful and uncertain method.

Frequently, however, it is not necessary for the pollen to be carried from plant to plant, or even from flower to flower. The flower can use its own pollen. Its stamens and stigmas are so placed in the flower that pollen will fall directly on the place where it is needed. In this way a flower is **self-fertilized.**

It has been proved that even those plants which can carry out their own pollinating very frequently produce better flowers and fruit when they receive pollen from *another* flower, or, better still, from another plant. This is known as **cross-pollination.** Then there are plants in which the flowers are either male or female, but not both. That is, unlike most flowers, some have stamens but no carpels (male), others carpels but no stamens (female). In some plants, the male and female flowers grow on the same plant, but in other kinds the male flowers (producing pollen) are borne on one plant, and the female flowers (with ovaries) on another. These, of course, must be cross-pollinated. You possibly know how the gardener assists the insects, as it were, in pollinating his vegetable marrows. If the weather does not favour the flight of insects, he takes a little brush and conveys some pollen from a male flower to the stigma of a female flower.

All this affair of pollination is taken very seriously by the gardener and the farmer, and more and more attention is being paid to the bee and its association with orchard trees and crops like clover. We are told that American growers are well ahead in dealing with it. One American professor has said that 'without honey-bees it is doubtful whether America would have sufficient to eat'. Fruit growers in New York State hire colonies of bees from professional



Geo. W. Judge

FIG. 7. BEE-HIVES IN AN APPLE ORCHARD IN KENT

bee-keepers, and distribute them throughout their orchards. Some orchards in Kent are being treated quite as generously, the hives being removed to other districts when the orchard bloom has faded (Fig. 7).

It is well known that certain apple trees (Cox's Orange Pippin is one of them) will not set seed if pollinated from their own flowers; other varieties have to be planted near by. Experiments made in screened cages have given striking evidence on the subject. For example, in pears, 428 fruits matured in the bee-visited flowers, only seven in those not visited. The corresponding figures for one kind of apple were 238 and sixteen. If the weather is very cold and wet at blossoming time insects may not be often on the wing. The result will be a poor crop, which is often wrongly attributed to frost.

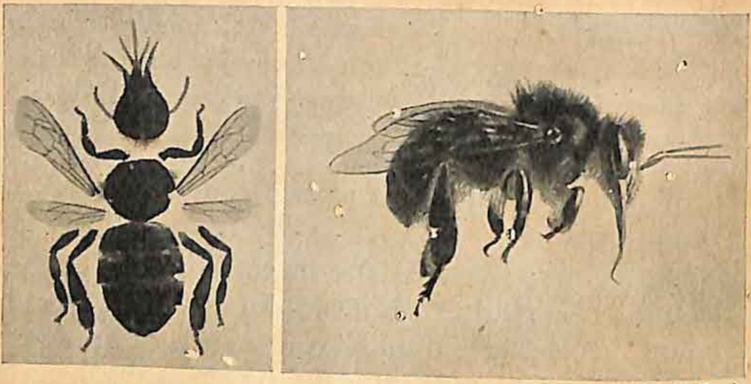
All these facts will prove to you how vital is to be considered the question of cross-pollination, and how markedly the bee stands at the head of the list as an agent in bringing it about. The next chapter will be concerned with the bee and its work.

CHAPTER IV

THE HONEY BEE

SINCE THE honey bee is the insect which fills the garden so cheerfully with its coming and going and renders such service to the flower-world, I think you ought to know a good deal about it—both the wonderful way in which its body is adapted to do its day's work and the manner in which that work is done. Use every chance which comes your way of watching the bees as they travel over the flowers. The pages following this will contain information which may help you in making your observations.

First of all, what does a bee look like? Use your patience to get a full answer when you can catch it at work. As is the case with all insects, its body is divided up into three distinct parts—**head, thorax** (that is, chest), and **abdomen.** (Fig. 8.) We will take a look at the head first. For such a small affair it is astonishingly well fitted up with varied parts. The big, prominent eyes are compound, which means that in place of the single lens which is in your eye each of theirs has thousands of tiny lenses. Projecting from the front of the head are two slender 'feelers'; these act like 'touch' or guiding organs, but they are of greater importance as being the organs of smell (Fig. 8).



Harold Bastin

FIG. 8. HONEY BEE

Left, viewed from above with parts separated; right, worker viewed from the side. (Note head, thorax, abdomen, wings and legs.)

The mouth parts of insects vary very greatly. Some insects possess mouths fitted for biting or chewing; some for sucking or licking. The honey bee finds no difficulty in doing all these things. Whilst you are reading these pages refer constantly to the diagrams which I have made for you (Fig. 9). Notice first of all the long, delicate, central filament. This is commonly called the bee's 'tongue'; it is grooved, and its tip is widened out into a minute 'spoon'. Its real name is **ligula.** On either side of the tongue are ranged two other long, thin structures, the **labial palps.** When the bee dips its head towards the nectar these labial palps and two soft jaws are pressed tightly against the tongue, and the whole forms a tube for sucking up the sweet juice. All these parts are folded back when not in use. Two strong jaws are present; they work like

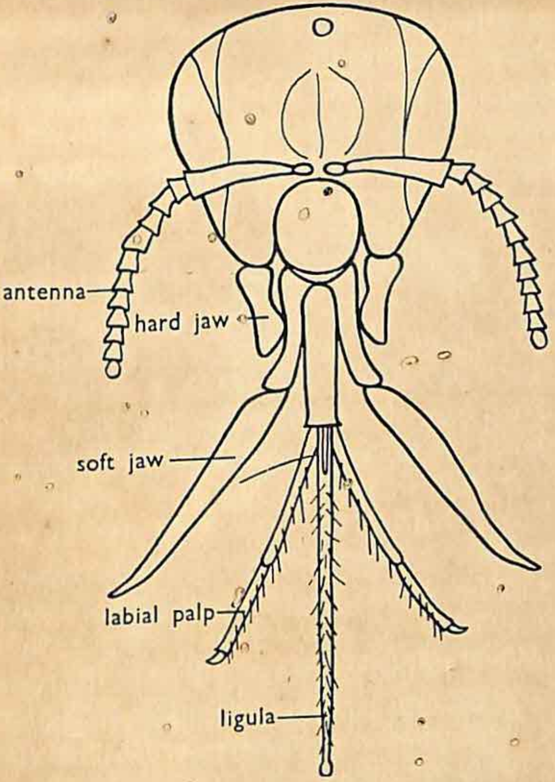


FIG. 9. HONEY BEE
Head of Worker.

a pair of pincers. Bees are classified as short-tongued, medium-tongued, and long-tongued. The honey bee belongs to the second group; its tongue is about 5 mm. long.

The bee's thorax is covered thickly with downy hairs. There grow out from it two pairs of wings and three pairs of legs. The wings are transparent and fragile-looking, but are really very strong; the two rear ones hook themselves on to those in front when the bee is in flight.

The legs are provided with various ingenious contrivances (Fig. 10). They end in claws by which they can cling, together with sticky pads which make it possible to walk upside down. The front legs are used to brush off anything which may soil the feelers. The middle legs have tips shaped like prongs; with these, pollen can be dug out from the baskets in which it has been firmly packed. Other parts of the legs resemble shears; they are needed for cutting wax. Stiff hairs are everywhere. But the nattiest fitments of all are those on the pair of hindmost legs; they do duty as market-baskets for bringing

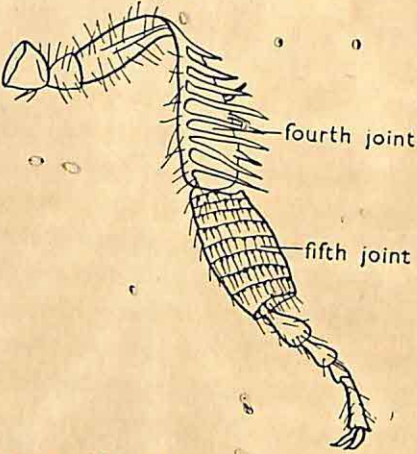


FIG. 10. HIND LEG OF A HONEY BEE
The fourth joint shows the pollen basket. The stiff bristles of the fifth joint scrape pollen from the opposite side of the body and transfer it to the basket on that side.

home pollen. One joint of each leg is hollowed out as this carrier, its edging being furnished by long stiff bristles which keep the overflowing mounds of pollen from tumbling off. The joint next to this is as good as a small bristly brush—a scraper.

What happens when the bee goes gathering pollen is this. The soft downy hairs covering the body dust off the pollen from the anthers like midget brushes. When the worker bee has got its body nicely powdered with the golden dust, the scraper parts of the hind legs set to work to gather it together. If the pollen is sticky the bee is saved some work. In case it should need it, it has brought out with it a few drops of honey, and this it uses to knead up dry pollen into balls. These it packs away methodically in the baskets. Very deftly the left leg employs its extra-hard bristles to clear the pollen from the dusty right leg (Fig. 10); then the right leg takes its turn. The procedure is all very neat and avoids waste of time and labour. So cleverly is the building up of the loads done that they may project far beyond the edges of the baskets without risk of falling off.

You may have seen and coveted one of these wonderful pocket-knives which are a bundle of gadgets; but could it compare with the pack which the little bee carries about on its body—sucking-tube, spoon, nippers, shears, climbing irons, brushes and combs, pipe-cleaner, shopping basket?

The bee's abdomen is fitted up with two more appliances. On the under surface are situated a number of plates from which issues, as required, the liquid which, when hardened, becomes flakes of wax.

That wax is needed for comb-building. Then at the tail end there is the sting—barbed and poisoned—the bee's weapon for guarding its home from intruders.

Try to imagine that you are watching what goes on within the home of the bees. I think you will wonder at the never-ceasing work, the perfect order, and the exact manner in which every individual carries out the special duties allotted to him or her. You ought to be able to single out one bee which has a longer, more slender body than any other; she is the **queen** of the hive. You see her feeling her way by means of her feelers, travelling from cell to cell of the honeycomb and laying a small white egg in each. She may lay as many as five thousand eggs in one day during the summer season. Standing about, always doing nothing, are the gentlemen of the community—the **drones.** They are flung out of the hive in autumn.

The great body of the hive population consists of **workers,** as it ought to do. They are all females, but they lay no eggs. The youngest of these, two or three weeks old, stay at home; they clean the house, build cells, guard the door, and feed the babies, each of which may get over a thousand meals a day. The older ladies are those whom you see in the outside world foraging for supplies.

During the winter months the bees keep themselves warm in a clever way. The hive then presents the queer sight of the whole host of bees bunched together in a big rounded cluster in the centre of the combs. There they are able to feed themselves. They actually keep themselves warm by taking exercise, for they are perpetually on the move within the solid mass of the cluster.

Have you ever examined a bit of honey-comb? No man could devise anything better fitted for the two uses to which the comb will be put. Space within the hive is scanty and has to be economized. The hexagonal cells placed end to end fit perfectly and no space is wasted. Their walls are firm and air-tight, built from the wax made in the body of the worker bee.

When you come to study insects which are garden pests you will need to know something about their early life. The bee will serve as a good example of an insect which passes through several distinct stages as it grows, so we will look at it now. Stage one was represented by the small white egg which the queen bee stuck to the bottom of a brood-cell. In stage two, the egg develops into a grub (**larva**). This is the fattening stage, when the nurses are pouring food into it. Stage three begins when the grub stops eating, spins a cocoon within which to wrap itself up, and sinks to rest (then called a **pupa**). During this period when it is hidden away the creature's whole being is transformed, bit by bit. In place of the rather shapeless lump called a larva there emerges, as stage four, the complete, complicated, beautiful, winged insect. For worker bees, the time required to fulfil all the stages is twenty-one days.

Let us see how the sweet juice of the flower is changed into honey. Is the hive something like a jam factory?

When warm spring days invite, out come the bees to make trial of the early flowers of crocus, narcissus and the like. When the orchards are in blossom the bees enjoy one of the peak periods of their harvesting; this is followed in June and July by the clover of the grassland; after that again comes the time for heather honey. Scouting bees go out in advance to bring in news about the best gathering-grounds, for time must not be wasted where the offerings are scanty.

How is the bee guided in the choice of flowers which it will visit? Partly by the brightness of their colour, especially blue and purple, but more decidedly by the scent of the nectar. The bee's sense of smell, which resides in the feelers, is very acute. The scouts are said not only to drink greedily when they find a plant rich in nectar, but also to spray themselves with the scent. On their return to the hive they give a dancing display, and scatter their scent around. Waving their feelers about the bees crowding around make themselves acquainted with the fragrance, and then go off in swarms to look for the source of it. In foraging, bees proceed according to definite plans. They prefer nectar which contains a great deal of sugar; when they find that a particular kind of flower supplies it they go from one to another of its sort, paying no side visits to others—a time-saving method. Within the flowers they know exactly how to set about their business, and never seem to lose a second.

I have already (p. 18) told a little about the bee's way with a flower, and I need not repeat it. Having taken in as much nectar as it can carry it wings its way, rather heavily, for home. It has the sweet juice bottled up in a special stomach, or crop, which lies in its abdomen. During the time it stays there the cane sugar of the flower juice is changed into two other kinds of sugar. You could not guess what happens when the laden bee gets inside the hive. She is able to bring back into her mouth the contents of her crop. She does not, as you might expect, pour them into the cells of the honey-comb. Standing round in expectation are some of the stay-at-home bees, and into their crops goes the partly digested juice. There it stays until the sugar change is completed. Then, drop by drop, it is squeezed out into the ready cells. Even now it is not quite fit for storage, for it contains too much water. The bees may not be scientists, but they know how to treat their store in a scientific fashion. By fanning the air with their wings they set up a breeze which speeds up the evaporation of the water. In scientific style again they test the honey, and finally seal up each cell with a cap of wax made by the plates on their abdomens. They have a better cover for their jam pots than the housewife has. Just take stock again. Besides all the tools etc. which I have already mentioned, here we have in the bee's abdomen a sugar-factory and a wax-making machine. Truly the bee seems fitted to lead a very independent existence.

Bees require nectar, pollen, water and a kind of glue for their house-keeping; all of these can be got from plants. Water is used in preparing food for the larvae and for other purposes; bees find it on leaves, in pools and elsewhere. The sticky substance is found on leaves of shrubs; it is used in many ways, including the mending of weak places in the hives. Nectar and pollen together form the food of the bee. The sugars of the nectar furnish the tremendous amount of energy which the bee expends in the course of its flights. Pollen is more complex than nectar, for it contains proteins (p. 99), fats, mineral salts and vitamins. It is very striking to find that within the tiny pollen grains there are packed away nearly every one of the food-stuffs essential to man's healthy existence; the absent starch and sugar are made good by the sugar of the nectar.

Honey, as we take it from the bee's cupboards, is mainly sugar in a state of strong solution; but it is flavoured with the scented oils and essences of the flowers. It also contains some of the mineral salts required by the body as well as a few other substances. Its food value depends largely on its requiring practically no digestion.

Every worker bee works hard. They have to do so, if they are to provide 400 pounds of honey and 40 pounds of pollen a year for their community, which may number between 40,000 and 50,000 individuals. Every pound of honey laid in store has cost 37,000 bee-journeys. So great is the strain at the height of the harvest seasons that a worker at that time lives no longer than eight weeks. The most convenient distance of honey-flowers from the hive is within a radius of two miles, though bees sometimes travel eight miles to get coveted nectar.

The clover crop is the farmer's business, of course; but you may as well know something about the debt which it owes to bees. The bee is an excellent pollinator of red clover, visiting these flowers in preference to many others. One investigator who counted thirty species of insects which visited this plant, found that 82 per cent of the flowers were pollinated by honey bees. This refers to the red clover which is sown in the rotation of crops on arable land.

Britain needs, and will need more and more, red clover seed harvested from her own fields. To secure that, she needs far more colonies of bees than she possesses. One difficulty which is recognized is that the corolla tube of red clover, at the bottom of which lies the nectar, is considerably longer than the tongue of the honey bee. Thus it is only when nectar is very plentiful and perhaps much diluted with water that the bee can reach it. This may discourage repetition of visits, for the bee prefers very sweet nectar. Attempts have been made to get over this difficulty by breeding a variety of clover in which the corolla tubes would be shorter.

The bee makes honey of excellent quality from the nectar of wild or Dutch white clover (*Trifolium repens* is the Latin name), and meadows are favourite haunts of bees. For the garden, there may be planted, in masses, such plants as broad bean, raspberry, lavender, catmint, monkshood, thrift and crocus. Roses, broom and gorse are visited specially for their pollen. Other 'bee-flowers' are *Anchusa*, borage, rosemary.

Humble bees are constant visitors to flowers; they are heavy enough to press down the lower lips of tight-mouthed flowers, and push inside to get the nectar. You might get a chance of watching the funny behaviour of one of them on a visit to a snapdragon, one flower which you should have in your bee-garden. The humble bee bounces a bit as he sits down on the cushion-like lower lip, which promptly drops, leaving the door open. In pops the bee, right in, and the door closes behind him; when he has had enough, he pushes his way out backwards. Columbines, too, should have their place in the garden. Their nectar is hidden deep down in a long spur. The humble bee has discovered an easy way of stealing it by biting a hole in the spur; it distributes no pollen by this tricky mode of procedure. The humble bee, with its long tongue (10 to 20 mm.), is a good pollinator of red clover. It has been commonly said: "No humble bees, no red clover."

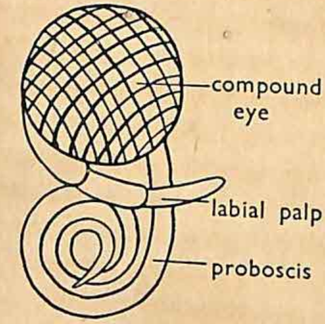


FIG. 11. PROBOSCIS OF A MOTH
Formed from union of jaws (side view).

* * *

Other pollinating insects differ from bees in the following characters. Flies have two clear wings. Butterflies have two pairs of wings covered with minute scales which they fold upwards when they are at rest; they have a long coiled **proboscis** (tongue). Moths have similar wings and tongues (Fig. 11), but the wings are outspread when they are resting. Neither moths nor butterflies have biting mouths like beetles (Fig. 12). Butterflies have very long tongues, whilst moths have the longest tongues of all.

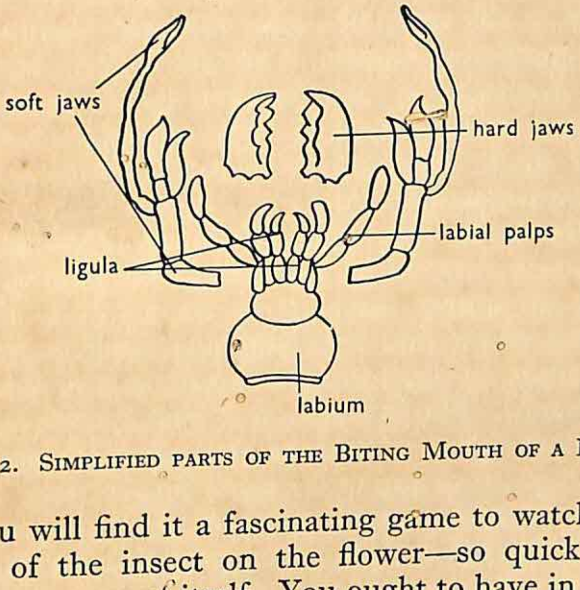


FIG. 12. SIMPLIFIED PARTS OF THE BITING MOUTH OF A BEETLE

You will find it a fascinating game to watch the ways of the insect on the flower—so quick and dainty, so sure of itself. You ought to have in your school library some of the delightful books which have been written about insects, and particularly about honey bees. What a thrilling business it would be for a school to possess an orchard, to keep bees, and to make a special study of the *Bee and the Blossom*—perhaps to write a little book about them for the school!

CHAPTER V

THE SOIL OF THE GARDEN

A SURVEY of the land which lies waiting for you to cultivate will naturally come near the beginning of your gardening course. You will want to see what your predecessors have done and decide how you are going to link up with it. You will, above all, set about an investigation of that soil which is to be your working material.

Where you live, I do not know. Perhaps your garden is situated on the heavy clay land of some Midland county, perhaps on the sandy heights of Surrey, or the thin soils lying over chalk or Pennine limestone, or the fine rich mixed soils of the Kent fruit-land. The first garden which I tried to cultivate was full of the worst kind of tough clay, and although roses and some other flowers were happy in it, vegetable growing was nearly hopeless. The garden which I work now represents the opposite extreme in soil—the poorest of sand. A third garden I knew long ago. Its cultivators rejoiced in the rich, loamy, well-drained soil of agricultural Annandale. More than one generation had toiled to build up its fertility; it gave generously to them; pests avoided it. In the pages which follow this, I shall talk about soils of various types. Study them all, and pick out for service what applies to the soil of *your* garden.

You must, in your trial work, dig deep. Make a hole, or trench, in that garden, so that you can look far down into the body of it. Three feet deep is not too much. Keep the sides of your trench vertical and clean-cut, for you want to trace out any **layers** of soil which may be present. Two, at least, you ought to find. That lying on the top will be darker, softer stuff than the one below it, which may suggest nothing much better than crumbled sandstone or clay rock. You *may* get deep enough in your particular plot to touch solid rock with your spade. I know some cottage gardens in a Yorkshire village where the diggers strike rock at about a foot and a half, which means that it would be useless to plant any but short-rooted plants there.

By carrying your observations beyond the bounds of your garden you may be able to get an idea of the manner in which 'soil' comes into existence. The layers visible at the top of a quarry-face often serve excellently as an illustration. So also does ground exposed in making deep cuttings for roads. In sections of ground like these you may trace the gradual progress from solid rock to top soil; who knows what generations of time it has taken to bring this about? Immediately above the rock mass, crumbled fragments of it of various sizes will appear as a rough layer. Previously, similar substance will have changed into the over-lying bed of finer particles more like the soil you generally see; but it is barren-looking, and the plant roots which have reached it are few in number. This layer represents what the gardener calls the **subsoil** (that is, 'under' soil). Now we come to the top layer of all, in which most of the plants growing on the spot spread out their roots. This is the **soil proper,** or **top soil.** Its chief characteristics are its dark colour and the quantity of refuse in it derived from the decay of bits of plants and animals. Nothing in the soil could be more necessary to its value than this dark substance. It goes by the name of **humus.** We shall have to learn a great deal about it.

All soils are not produced in the same quiet, very slow way from the rocks on which they rest. Some of the cottagers in the village of which I spoke, where some soils were so shallow, were more fortunate in having their houses, not on the side of the hill, but down on the flat land near the stream. Often in past years the stream when in flood had carried down quantities of mud and sand, and spread them over the near-by land. It had become first-rate, deep soil; the ingredients were mixed in size and in their chemical nature. Many of our market gardens are laid out on such **alluvial** soils in wide river-valleys. If you have soil of this kind in your school garden you ought to get grand results.

Turn over the soil in several places in your garden, run some of it through your fingers, notice its colour, give an eye to the plentifulness of stones. Ask yourself if it belongs to either of the extreme types which I have mentioned, or if it falls somewhere between them. If it is a very bad specimen of soil you will have to consider ways of improving it. You might also make a simple experiment to check, somewhat roughly, your observations. Into the tallest glass vessel you can get, put a big handful of soil; then fill up nearly to the top with water. Shake up well, and then leave to settle. The particles of soil will arrange themselves in layers according to weight, the heaviest dropping first. The finest clay at the top may have above it a layer much darker in colour, and of course lighter in weight. This would be humus, some of which may continue to float long after the rest has subsided.

For convenience of reference, workers classify soils according to the size of their grains, and talk of sandy, silty, and clay soils. The gardener's preference is for a loam, which is a mixture of sand and clay, and which he considers at its best when lime is present in it.

Here is an experiment by means of which you may test the truth of the statements which I shall make in the next few pages. Fix up, by means of retort stands if you have them, four large glass funnels lined with filter paper, having a dish under each to receive drips of water. Into funnel *A*, put dry garden soil, rubbed down; into *B*, sand; into *C*, powdered clay; into *D*, sand mixed with humus. Have ready four measured, equal, quantities of water. Plan so that these quantities can be poured into the four funnels *at the same moment*; make a note of that moment. Watch for the first drop to issue from the funnel in each case and make a note of the time. The last drop also must be chronicled. Now you will be able to compare the times taken. What do you ascertain by doing this? Proceed a little further. Measure the amount of water in each receiving dish; subtract the figure from the amount put into the funnel. What does this tell you? Compare the results in all four cases. Do I tell you the truth or not?

Before we pass on to discuss other respects in which soils differ from one another, I will try to make clear to you the way in which the water-supply of the soil is connected with the roots of plants. One may imagine at first that it would be a simple matter, that water is lying there, and the roots drink it up. There are, however, complications which I may be able to sort out for you, at least in part. You, on your side, must exercise your powers of imagination in making pictures in your mind of what you cannot see. I shall have to ask you to believe in some things I say, even if you do not yet understand them fully.

You will understand readily enough that when there is abundance of water in the soil, the spaces will be well filled; but, as the water is free to move it will, like all water, try to get to a lower level. It will slip from space to space, away from the surface. That is one condition in which soil-water may exist.

Even when this 'free' water has drained away there will remain for a long time thin films of water which will adhere to the surface of every grain of soil. They will stick particularly hard if the particles are of the size of those of clay. You may have heard of a force called **surface tension** which draws the molecules of a liquid towards one another, especially those on the outside. This it is which makes the water cling to the solids in the soil. The root-hairs have to drag it away, as it were. If these 'skins' of water grow very thin, as they may do near the surface of the soil in hot, dry weather, they may break up, and the soil is said to be 'air-dry'.

I think I will mention a third way in which water may be held in the soil. You may not find the idea easy to grasp, but as it is of the utmost consequence to the plant's food-getting you had better try. If you fail at first, you need not worry too much.

Here is an experiment which will at least give you something definite to go on with. Fill a tall glass jar nearly full of water, and put a small quantity of clay into it. Shake it up well, and then leave it for a long time to settle. Most of the clay will fall to the bottom of the jar, but you may have to wait *many days* before the water above this becomes clear again. It looks hazy. The cloudiness is due to matter so finely separated that you need a microscope to distinguish the individual morsels of it. You must not confuse this floating substance with the bits of humus which remained suspended in the water in the experiment on p. 38.

Scientists have worked hard in recent years to get at the secrets of these nearly invisible bits of matter. They do not consist of a new kind of matter, but are merely the familiar clay and humus divided up over and over again. When they are in this condition they are said to be reduced to a **colloid** state. You should memorize that new word, as it will be useful. Where do you find colloids exactly in the actual soil? You must picture them as spreading themselves all over the surfaces of the ordinary particles of the soil, just like a smear of jelly. There they stick.

Now what concern are they of the plant's? To answer that, we must trust the scientific workers, and they tell us that these colloids exercise a peculiar attraction on water and on many substances which the roots of the plants are eagerly seeking as food. And what they manage to draw into themselves they hold on to, hard. Can you imagine, then, that jelly-like skin on the particles as being both a drinking-trough and a larder to which root-hairs attach themselves like leeches? (Fig. 1.) Some of the food substances which the colloids hold in their grip would otherwise be washed out of the soil and be lost to the plant.

The rootlets and the root-hairs lie in the closest contact with the grains of soil and water (p. 4). You are here looking at what we may call *the crucial event in the existence of the plant*. If it succeeds in drawing that water and what it contains through the soft, thin walls of the root-hairs into its interior, it has a chance of living. If not, it will die. So! two lessons emerge for the gardener. One, treat the little roots gently. Two, see that the soil contains the requisite amount of water.

We will now consider the behaviour of markedly sandy soils, and of clay soils, which differ of course in the size of the matter composing them. Two questions have to be answered about them. The first is, what amount of water are they capable of holding; that sounds like their capacity as water-tanks. The second asks if they allow water to pass freely into and through them; has the tank many leak-holes?

The comparatively large grains of sandy soils are separated by correspondingly large spaces, often spoken of as 'pores'. These spaces, taken all together, give us the water-storage capacity. Do not be misled by the size of the individual spaces into thinking that this must be large; the fact is that the sum total of them proves to be smaller, the larger each particle is. Water can enter such soil easily, and moves through it freely. When clay is mixed with the sand it fills up some of the spaces, and the movement of water is slowed down; this is an advantage to the cultivator in most cases.

In clay soils, the minute, extremely light particles do not shake themselves into place tightly. The whole mass is riddled through and through, though it does not look like it, with the smallest of spaces; they form something like a meshwork of very fine tubes. They are so numerous that their small size does not prevent the complete sum of their space from being very high. They act, therefore, as a very capacious tank. When we seek the answer to our second question with respect to these soils, we learn that water will have difficulty in getting into the tubes, and, once it is in, it will move very slowly. Clay soils will therefore retain water well, and may indeed become water-logged, that is, permanently saturated with water—a condition very unfavourable to the growth of roots.

You, as gardeners, may have to handle one of the unfavourable soils, and may want to devise ways of improving it. Is it one in which there is too great a proportion of clay? That would mean a badly drained soil, one which could not be aerated properly, one which was cold, because water needs much heat to warm it up. It would tend to be sticky in wet weather, to turn into hard, baked clods in hot dry weather. I know that kind well. If it is possible to work plenty of sand and grit into the clay when in its most workable condition, a partial cure will result. Half-decayed vegetable manure mixed in thoroughly will lighten the mass. The application of lime is a most valuable corrective; but it needs to be repeated systematically; it acts on the colloids and makes them group themselves into what the gardener calls 'crumbs' of soil, which are just right for use. Frost helps towards spring cultivation of clay ground by breaking up lumps when the water present is changed into ice. To give it the best chance the ground should be dug in autumn and left in rough ridges throughout the winter. You must be careful not to work heavy clay soils when they are wet.

Sandy soil will probably be poor, hungry soil, from which the nourishing salts have been washed out by the quick passage of water through it. It will tend to be over-drained. It will be warmer than clay, lighter, easier to handle. But it will have to be fed liberally, if possible with abundance of farmyard manure; this not only nourishes it but also helps to retain water. The treatment will have to be applied repeatedly. All available plant refuse, including fallen leaves, may be worked in to its advantage. Probably lime will be lacking; this, as well as many plant foods, will have to be renewed constantly. The reclamation of great tracts of sandy waste has been successfully carried out in Denmark and other parts of western Europe. One part of the procedure is known as 'green manuring', which means sowing a quick-growing crop and ploughing it back into the ground when it is half-grown. Usually a *leguminous* crop is chosen, such as lucerne, clover or beans, because these plants, for a special reason, leave the ground richer than they found it (see p. 122). The plan may be practised on a small scale in the garden. If a plot of not very fertile soil is clear of crops by the end of August, it may be lightly raked over, and a quantity of mustard seed scattered over it and raked in. If the green growth is dug into the ground before winter weather sets in it will improve the soil with additional humus.

Up to this point I have compared soils mainly in respect of the size of the grains composing them. We have to think also about their chemical qualities. Sands differ from clays in the principal chemicals present in them, but with that we will not concern ourselves here. We must, however, pay a good deal of attention to what farmers and gardeners say when they talk about land as being 'sour'.

A little chemistry comes into use now. What word do you use to describe the taste of an unripe apple or a squeeze of lemon juice? 'Sour' or 'acid'? They mean the same; the chemist uses 'acid'. Probably you may not know the opposite of 'acid'; it is 'alkaline'. These two qualities of substances must be compared. Take the acids first to see how they behave. You are sure enough about their presence in apples and vinegar and sour milk; but you cannot test everything with your mouth. There exist much stronger acids, like sulphuric acid and nitric acid. The chemist tries to find out if one of these is present by bringing into contact with the suspected substance a piece of blue litmus paper. This paper should be among your equipment, and you can experiment with it yourself. If acid is present, the blue colour will change to red—a perfectly sure sign.

Lime and lime-water are the alkalies which you are likely to come across; ammonia is another. When red litmus paper is applied to these, it turns blue. When the right amount of an alkali is added to an acid the peculiar properties of both of them disappear; the mixture is *neutral*. Relief is given when a person is stung by a bee by the application of ammonia, which counteracts the acid of the sting.

Acid garden or field soil is usually disliked by plants and by their growers, although there are exceptional plants, blackberry for example, which seem to prefer it. The acids which exist in soil are numerous. Some of them are organic and some inorganic. I am introducing these words purposely that you may learn their meaning, for they are continually cropping up in gardening talk. **Organic** matter is that which is living or has once been living—for example, a rabbit alive or dead, a daisy, a rotten leaf. **Inorganic** substances have never had life; for example, a brick. The soil acids may be derived from the decay of organic matter lying in the soil, or from carbonic acid brought down from the air in rain, or from several other sources. Badly drained soil is likely to become 'sour'; water containing much acid will tend to stagnate in it. Such soils will lack air. One remedy is to drain them well; another is the breaking up of the close texture of the ground by digging and admitting air. Exposing the soil in rough ridges during the winter months gives frost a better chance of sweetening it. The most direct and speedy way of curing acidity is to apply lime; this, you will remember, counteracts or neutralizes the acids, provided there is enough of the lime.

Leaving the question of sour soils, we take up that of soils which may be described as neutral; these also require treatment to make them favourable to plant growth. A few pages further on (p. 76) you will read a good deal about the great need for lime in soil, which means that soil should be alkaline.

One of the gardener's jobs is to find out whether or not his garden needs liming. In many cases, gardens do not get enough of lime. How is the gardener to decide whether to lime or not to lime? I do not think that you will ever find an experienced gardener making an analysis of soil to estimate its acidity or alkalinity. As I do not consider that you could make an analysis which would be of practical service, and you can use your time to better advantage, I shall not suggest such an experiment to you. A gardener who is in serious doubt can send samples of soil to a research institute for analysis and advice. Even the information thus obtained is nowadays often regarded as of doubtful value, owing to many varying factors in the garden. The gardener and the farmer make the growing plants tell them how their roots are being served. If sorrel, daisy and plantain flourish apace as weeds, then it may be taken as a sign that lime is scarce round their roots. Rhododendrons and azaleas dislike lime; so do gorse and broom.

The gardener may experiment through his plants to ascertain if they are getting sufficient lime. Let him set out a trial row of some plant which demands lime for growing really well; peas will serve, or beet. Into the top soil of one half of the row he will work a dressing of lime. If the individuals of this half are distinctly superior to those in the unlimed half it proves that the latter are being, to some extent at least, lime-starved.

CHAPTER VI

THE TEMPERATURE OF THE SOIL

DOWN WITHIN the soil, often pretty deep down, the roots of the plants carry on the work which is keeping the plant alive. You would not feel very fit for work if you were 'starving of cold'. Neither does a plant root. Neither do the hosts of microscopic living things with which the soil is crowded and which you will learn later are essential to the life of all the great plants and animals. For that reason, the gardener must pay attention to the way in which the soil is warmed.

In connection with this matter of temperature, the presence of air in the interspaces of the soil must not be forgotten. The roots require air for breathing just as the leaves do, and just as you do; so do most of the small soil-dwellers. When I see top soil battened down hard, I always feel that I must stir it up to let air in to little mouths gasping for it down below.

The ground is heated by the rays of the sun, and this is true for the soil particles, the water and the air mixed up with them. You have to reckon with several facts in studying the effect of this on plant life. As a rule sun-heat does not penetrate deeper than three feet, whilst it is only in the few inches at the top that changes of temperature take place quickly and in great degree. During a sunny day the temperature of the surface soil is higher than that of air overlying it. Some soils heat up more rapidly than others. Clay soil is one of the slowest because it retains more water, and water takes five times as much heat to raise its temperature as is necessary to raise that of the solids composing the soil. Dark-coloured soils absorb more heat than those of lighter colour.

Here is an experiment which will give you a convincing idea of the way in which plants respond to differences of temperature.

Fill three pots with soil or wet sawdust, and in each of them place three broad beans which have been soaked in water for a day. Let pot *A* be kept in a room at an ordinary temperature; place pot *B* near a radiator; enclose pot *C* in a tin box containing ice which is renewed as required. Young shoots will appear first in *B* and grow quickly; those in *A* will be later and slower of growth but stronger; very likely no shoots at all will show in *C*, or only very late and in poor condition.

The truth is that a plant may be starved in the matter of water even when its roots are bathed in it. You can see an example of this on a great scale in autumn when the leaves drop from the trees; the ground has become too cold for the roots to replace the water which is continually passing off from the leaves. Only when the sun warms up the soil in the following spring do new leaves get their chance of water and food.

Every plant seems to have its own ideas as to when it is warm enough to expect its roots to work. They refuse to do anything when the temperature falls below a certain point, and they do their very best at some particular temperature which suits them. In this country the average minimum below which they cease to work is about 41° F., and the optimum (best) is about 99° F. Remember that these are soil temperatures, not those of the air. The rules apply to the behaviour of seeds as well as roots.

To what practical use can you put these theories about the warmth of soil? They have to be kept in mind constantly. When you are watering plants, outdoor or in pots, take care not to chill their roots with water from a cold tap. Let it stand in the sun until it gets warmed up. When you are watering very dry soil remember that the spaces in the top layers may be filled with dry air, and the first sprinklings of water will find difficulty in entering. This explains why light summer showers often do little good; the water evaporates before it can get far inside the soil.

Vegetable matter as it decays gives rise to a certain amount of heat. This explains why manure is used to make a 'hot-bed', and is piled round rhubarb to force it into earlier growth.

The amount of heat received by any piece of ground depends on its aspect and its slope. If it slopes towards the south it is in the most favourable situation for getting sunlight. It will be a good choice for seed-beds unless there are other reasons against it. Do not place such beds in heavy shade.

One way in which you can tell a good gardener is by his always hitting upon the right moment to sow his seeds. Some say it is by instinct, some by experience; probably it is because he uses his brains to judge conditions. One thing at least I have learnt through sad experience is not to be in too great a hurry to get seeds into the ground in spring. A few warm spring days make you feel hopeful, and you dream of early crops. You forget that though you may be feeling the warmth of the air around you the soil, below the surface, is still nearly as cold as it was before. The seeds placed in it can do nothing. The warm spell may soon pass, and they will probably lie inactive till they rot. At any rate some of them *never* show face above ground. You plan sometimes to secure a succession of crops of a particular vegetable such as peas, and make several sowings at intervals of perhaps three weeks. You may be disappointed to find that the first and second sowings ripen at about the same time; the ground happened to be too cold for the first lot to make an early start. It is better in such cases to make the first intervals longer rather than shorter.

More and more during recent years gardeners have been using portable glass covers of various types to hasten the growth of spring plants by protecting them from winds and securing for them a higher temperature in which to work. These appliances are called **cloches** (from the French meaning 'bell'); they are now made in many sizes and shapes. The school ought to possess a number of them of fair size. The cloches capture and retain what heat is available, and lessen the great loss of heat by radiation at night. They are most useful for germinating seeds. You ought to experiment with them in various ways, covering up part of your seed-bed for example and comparing the results with those obtained from the uncovered section. Try encouraging a few of your vegetables to speed up their progress. I have seen carrots which were sown under cloches on February 23; were decloched on March 28, were ready for gathering on May 3; and some of which were six inches long on May 30. Try if you can beat that record. Turnips can be hurried up in the same way.

Frost can behave as a very good friend to soil. The school should keep records of any outstanding effects which can be traced to very severe or very mild winters. In the first place, freezing improves the texture of the soil, and is specially beneficial to clays. The wise cultivator sees that it gets its best chance by getting his deep digging done in autumn, and leaving the surface rough and in ridges. Water present in the soil freezes, and in doing so increases in volume; it forces apart the solid grains, holding them together first, of course. The soil in this state looks puffy and swollen. When the thaw comes the particles fall apart, giving rise to a more crumbly soil. You might try to find out the depth to which the soil in your garden freezes; sometimes there is only a thin hard crust on the surface. The great increase in the volume of water when it changes into ice is very evident in severe winters; it is the reason why water-pipes burst in hard frost, the break coming to light when the thaw comes. Prove the fact with an experiment of your own. Fill a glass bottle completely with water and cork it up securely. Leave it out of doors when the temperature is very low; when the water freezes the glass is shattered into pieces, and you may have left a solid bottle of ice.

Accompanying the freezing of the surface-water in the garden soil there may be a curious happening spoken of as 'frost-lift'. It is seen clearly in the behaviour of shallots, which can be planted out with safety in the middle of winter. They should be buried to such a depth that only their tips show above the ground. Looking on your bed after frost has been busy on it, you may see that some of your bulbs, including those which have already formed roots, are apparently heaving themselves out of the soil. Surface freezing plays some part in this; but the push upwards is derived chiefly from the movement of water upwards from the lower soil. This 'frost-lift' sometimes goes to the extreme of tossing young, slightly rooted plants out of the ground. The only remedy is to plant firmly, and to harden the ground well after replacing the plants.

What effect has frost on what is alive in the soil? Very seldom are roots frozen to death; but the gardener fervently hopes that several other things will meet their end. All manner of pests, animal and plant, spend the winter resting in the soil. Some of them perish in severe frost, but there are others which cold cannot kill. We have, fortunately, many seeds which are extremely hardy. We have only to think, too, of how vegetation survives in the Arctic regions to realize how true this must be for both plants and pests.

CHAPTER VII

THE PEOPLES OF THE SOIL

BACK AND forth along the pavements of our big cities crowds of people hurry and jostle each other. Their numbers are as nothing when compared with the multitude of living creatures which are competing for a living within the dark places of the soil. Every effort of every one of them has only one object—that of getting food for itself; at the last, it must also leave offspring behind it if the race is to be carried on. Some of the larger specimens of this population you can recognize by sight; but the many millions need the microscope to disclose their existence. We will attend to the bigger folk first.

The most famous of them is the **earthworm.** The great scientist Charles Darwin studied its habits for many years, and wrote a book which made it famous: you may be able to borrow this book from a lending library. Darwin was full of praise for the services which earthworms render to plants. It is a thoroughly interesting pursuit to follow up their doings. Keep a look-out for them in the garden soil; if they are numerous, it is a sign that that soil contains at least a fair amount of lime; they do not like acid soils. I have few in my poor, sandy soil. You may learn something by noticing the depth at which they are most numerous at different seasons.

Examine one of them; it is clearly marked into rings or segments; its skin is slippery; if you draw your finger from tail up to head on the under side, you will feel lines of short bristles which are hooked and point backwards. Set the worm in movement; it actually *claws* its way along by digging these hooks into the soil. Have you ever seen a thrush trying to haul an earthworm out of a hole within which part of its body was wedged? It must give many a tug, for the little hooks act like barbs.

If you want to catch the earthworms feeding you will probably have to go hunting at night furnished with a small torch, for they do not usually come to the surface in daytime unless they have been flooded out. If you are lucky, you may see one lay hold of a bit of leaf or grass and drag it down into its hole. It may eat it later on, or it may use it as a lining to make its burrow more comfortable. There, on the ground, it trails about, feeds on bits of vegetation; it may make a little heap of stones to protect its burrow, and it gets rid of the waste matter from its body. How is that burrow made? The worm does not bore a way through the soil; it *eats* its way along. The soil which it swallows contains bits of plant waste which serve it as food. Everything swallowed gets ground to powder in a strong gizzard. When the worm comes out for its nightly airing, it leaves what is useless to its body thrown up in the form of the 'worm-casts' which no doubt you have seen.

We must learn how the earthworm helps the plant. First, its tunnels loosen up the soil, which is always an advantage, by helping air and moisture to circulate. Secondly, when it is carting in its body soil from deep down up to the surface, it is doing the same kind of work as digging or ploughing. Darwin reckoned that the whole soil to a depth of ten inches in natural land is digested and cast up by earthworms once in fifty years. Thirdly, in recent research the worm-casts have been analysed and found to contain a greater proportion of plant foods than ordinary soil. For example, they have five times as much nitrogen and 40 per cent more humus. So the earthworm is constantly manuring the land. Gilbert White, the Hampshire naturalist, who lived in the eighteenth century, said: 'The earth without worms would soon become cold, hard bound, void of fermentation, and consequently sterile.'

Beyond ravaging a few potatoes left in the ground too long, and making lawns look somewhat untidy, earthworms seem to be not only guiltless but also useful; so do not slice them in two with a spade.

We pass on to consider less welcome soil-dwellers. Your garden may suffer from **wireworms,** which are not true 'worms' at all, for people use the term 'worm' very loosely (Fig. 13). Nobody has a kindly word to say for a wireworm. It is a grub (p. 29), the larva of a beetle. It may lie around in the soil for three years, eating most of the time, ruining

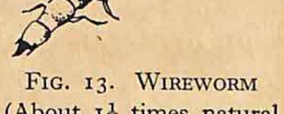


FIG. 13. WIREWORM (About $1\frac{1}{3}$ times natural size.)

roots all the year round. It literally 'mows' into pieces the roots of grasses.

Another underground enemy of a similar kind is the **leather-jacket.** It, too, is an ugly grub, living on roots and specially destructive to grass. It changes into the fly which you may know as daddy-long-legs.

These three do not exhaust the list of the big inhabitants of the soil; search out a few more.

Now we come to the hordes of the nearly invisible creatures, which are not so easy to understand, but which, as you will see, are of supreme importance to all life. Some of them belong to the animal world, and are called **protozoa.** The more numerous are plants, the **bacteria** which are so much talked about. Research workers tell us (and I think we may believe them) that in a single gram of soil there may flourish—partly, maybe, by eating one another—45,000,000 bacteria and 1,000,000 protozoa. Can you credit it?

We can all see the results of their work in many places around us, even if we cannot see the creatures themselves. They are not the only scavengers which Nature employs to keep the earth pure and sweet, but they are first-class hands at the business. Wherever a bit of plant stuff lies decaying, there they are busy. They soon reduce an old cabbage blade to pulp, and later to soil. To serve one of my own ends, I gather into a mass such seemingly useless things as grass cuttings, old leaves of vegetables, and so on; sprinkling some soil among them, I leave them for a time (p. 71). If I turn over the heap after a few weeks I find a disagreeable looking mixture about which you would at once say, 'How rotten!' That is exactly what I wanted it to be. Nine months or more after starting the operation I open it up and investigate. It is much shrunken now. Probably not a vestige of leaf or stalk would be there; in place of the whole collection of plant remnants there will be a heap of darkish crumbly soil. I have learnt that it is bacteria which work this kind of transformation.

Before saying any more about their doings, I ought to give you an idea of what the little things look like. Considering how small and how simple they are, one marvels all the more at what they can accomplish. I have already spoken of plants as being made up of 'cells' (p. 13). Well! a bacterium consists of one solitary cell—no root, or branch, or leaf; yet it keeps itself alive and active. The commonest shapes in which they exist are minute spheres or short rods. Sometimes in the course of the life

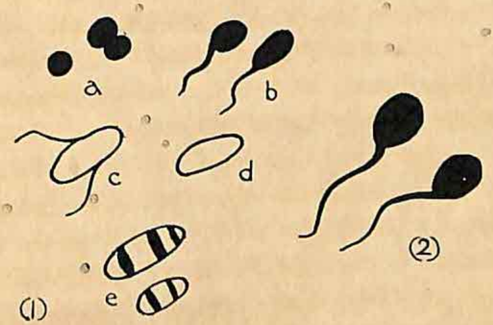


FIG. 14. BACTERIA

1, The bacillus in nodules of a broad bean (*a–e*, successive stages in its development); 2, bacillus which works in compost-heaps in building up nitrates. (Highly magnified.)

of some of them, two thin, whip-like extensions grow out from their body (Fig. 14). By lashing these about the creature contrives to move a little way. Somebody has estimated that it would take two hundred years for it to move a mile! Although it would seem impossible to tell one from another of these workers, there must exist decisive differences, for they behave like specialists, who devote themselves mainly to one kind of work. The scientists have named several groups of them, according to the work in which they specialize.

We will now go back to that work. What was done on my rubbish heap could be divided into stages. In stage one, certain sets of bacteria crowd all over the dead plant cells and get busy with the breaking up of them. It rather reminds one of the breaking up of an old ship, to get some of the fragments for further use. What are these bacteria after? Food, always. There is one element which enters into the make-up of many foods which I must mention here; I shall have more to say about it later. It is nitrogen, the gas which forms four-fifths of the air you breathe. Every cell in *your* body requires nitrogen; the bacterium cell has an equally urgent need of it. You might almost say that it knows that in the cells of these decayed leaves and stems there is plenty of nitrogen. It devotes itself to the getting of it, at any rate. Somehow, it fetches it out and feeds on it.

In this manner the bacteria keep themselves alive; but if they did nothing more, their affairs would not concern us greatly. But they do. It is a fact of immense importance that they generally set free from the decaying material far more nitrogen than they can use for themselves. They do not trouble themselves about that.

That extra nitrogen starts stage two in the history of the rotting plant scraps. The actors which take charge now are other groups of bacteria. These individuals are 'builders', not 'breakers'. From the material broken up by their predecessors they proceed to manufacture, as if they were chemists, quite complex substances. I will mention only one example—*nitrates*. Notice the word; you can guess that it relates to nitrogen. Your workroom should be provided with specimens of nitrates; gardeners often use them; see if they will dissolve in water. They are among the most valuable foods which plants require. I would expect to find quantities of them in my rubbish heap after the bacteria had had their way with it, and I would use it all for manuring my plots.

Now let us take stock of the above paragraphs. Your minds must be fixed on that nitrogen; never forget it. The breaker-bacteria attack a handful of grass; some of the nitrogen derived from it is worked up by the builder-bacteria into nitrates. After they have been dissolved in soil-water these nitrates may enter the roots of grass plants, and go towards the forming of new leaves. The cow eats the grass, and from it manufactures milk and beef. We drink the milk and eat the beef, and get from them some part of the supplies of nitrogen demanded by the cells of *our* bodies. It seems a round-about way of getting nitrogen when we live in a world of air full of it! We depend on bacteria to feed us.

If what I have outlined were the entire story about the way in which plants and animals obtained their nitrogen, it would mean that a fixed amount of the element would be all the time travelling in a circle from dead grass to dead grass. It is not so. That practically inexhaustible reservoir of nitrogen which is the atmosphere can be drawn upon for replenishing and enlarging the food stock. One mighty power acts in the sky. A lightning flash can compel nitrogen to unite with hydrogen and oxygen to form nitric acid, which falls to the earth with the thunder-rain. In the soil it is joined with other substances to form nitrates.

The lightning, however, could not be depended on for regular contributions from the air. We have to betake ourselves again to the soil and its bacteria. It is a fact of tremendous importance that there are bacteria specialists which are able to do exactly what the electricity did, that is, make the nitrogen of air give up its freedom and join up with the other elements which constitute nitric acid and nitrates. *The existence of the whole living world depends on this power of the lowly bacteria*, each a single cell. I shall have more to say about a certain family of these specialist bacteria when we come to deal with peas and beans.

I must warn you that I have made the history of nitrogen within the soil to appear much simpler than it is in reality. It involves a series of changes which no one yet understands fully.

We must examine our duty towards our bacterial benefactors. First and foremost, they must have plenty of air, so we must see to it that the soil is loose enough for it to circulate freely; it must not be water-logged, if we can prevent it. Bacteria cannot work properly in sour conditions, therefore lime must be applied if acidity needs to be corrected. A certain amount of water is necessary. Like the larger plants, bacteria are inactive below a certain temperature (p. 49); they lie dormant, or asleep. A light, sandy soil is not one favourable to their activity. It is too dry and probably lacks lime. One may dig vegetable fibre into it, and, at the end of weeks, find it almost unaltered.

Bacteria are not the only very small inhabitants of soil; there are microscopic fungi and other organisms. Some of them we will meet with when dealing with the cultivation of certain vegetables.

CHAPTER VIII

DIG FOR FOOD

NOW WE go to our digging.

Why should we dig? That is quite a proper question to ask. Whilst your hands are busy with your tools, keep your mind active all the time enquiring into the why and wherefore of every operation. Never be content until you get answers from yourself or from somebody else. I will offer you part answer to my own question; your experiences should enlarge on it.

Throughout many months of the year, whilst the crops are on it, the garden ground is settling down into a harder, closer condition, except perhaps in the top few inches. Your digging is intended to break up this compact mass, to loosen its texture so that air and water may penetrate and move about at a reasonable rate. Then, your spade should be so handled that the soil which it lifts is overturned, the lower layers being placed uppermost. This secures a mixing of the ingredients which plant roots need. If the soil has to be manured, this is a convenient opportunity for mixing it thoroughly with the soil. If deep digging is practised, the subsoil (p. 37) can be improved, and, in time, be made to increase the depth of the soil.

I have no intention of setting out details of the method which you will employ in digging your school plot. These can be settled only on the spot, and under the direction of your teacher. I will urge you, however, to carry out all directions *exactly*; doing so is a habit well worth acquiring and applying to all the work you undertake. There are, too, excellent opportunities in digging your plot for devising the most methodical way of tackling it—the quickest, most labour-saving. You will be given rules for carrying tools safely, for keeping them in good order when in storage. Try to see the reasons for all of them.

The best season for digging has to be decided. If you live in the country you may see that, early in autumn, the farmer starts his ploughing, and that he leaves the steep ridges rough for the winter, unless he is sowing a winter crop. The garden will benefit equally if so treated. I have already explained why. Heavy ground gains most by being exposed to severe weather for months. The work may be started as soon as the ground is cleared of crops. There is always a great rush of work in early spring, and if the ground lies there ready for you to take it over and get your sowing or planting in hand you will find how much you have gained by your autumn labours.

The state of the ground after heavy or prolonged rain often forbids the working of it for a considerable time. A sandy soil will drain fairly dry in the top layers quickly, and will come to no harm if you start on it when it does not encrust your boots. But to work a clay soil at such a time means more than a hard, dirty job, for it is most harmful to the soil itself. It becomes stickier than ever, cakes into lumps which become stony clods when they get the sun on them. Such is bad treatment for the bacteria in the soil.

The digging which is usually practised turns over the true soil only. Do not be satisfied until you are a real adept at it, and can show workman-like results. After the scheme for dealing with the plot as a whole has been made out with pegs and line, there follow your personal efforts. The first trench has been cut, and then you begin filling it in. First you mark off by a cut made at right angles to the trench the width of the spadeful you mean to take. Then your spade must be driven down vertically to its full length. Its load of soil is lifted and turned into the waiting furrow. When you have finished your row the sliced edge should stand out like a clean-faced wall. You can make your digging a quite rhythmic performance, and when you do anything 'rhythmically' you do it in the best style, the one which uses your muscles with less fatigue and which strengthens them. This is well seen in your gymnastic exercises. A fine gardener whom I once saw giving such a demonstration of digging, which looked so 'easy', added the remark that if diggers would always straighten their backs after every turn-over of a spadeful they would not be troubled with backache.

If manure is to be placed in the ground at digging time, it should be scattered over the face of each line of overturned soil, that is, on its sloping surface; this distributes it more evenly through the soil than placing it at the bottom of the trench. It is, of course, covered with the next spadefuls of soil. As certain crops require the ground to be manured a long time before they are put in, we have in this practice another argument in favour of autumn digging. Digging to the depth of the spade is known as digging 'one spit' deep.

'Bastard trenching' means digging two spits deep, and 'true trenching' three spits deep; one of them may be put into rotation once in every three or four years. 'Trenching' goes far beyond mere 'digging' in its objects. It penetrates into the subsoil, which is usually barren of roots and humus. Having reached it, we proceed to break it up thoroughly with a fork and to remove it layer by layer, taking great care not to mix it up with the valuable top soil. These layers must be replaced in the order in which they are taken out, and as much manure and decaying vegetable stuff as we can spare must be mixed in with them.

Increased attention is now being paid to the subsoil as possibly containing much which is of value to plants, and to methods of bringing it within their reach. It varies greatly as between sandy and heavy soils. In the former, it will probably be poor in every respect. In the latter, there may lie stocks of nitrates which have been washed down from the upper soil. Many plant roots are able to penetrate very deep down, and if the subsoil is loosened up by forking and by vegetable fibre put into it, these will thrive more readily. Repeated trenching and deep manuring really deepen the upper soil by adding to it layers enriched by humus. At the same time, the store of water is increasing, because the roots are encouraged to tap the deeper-seated supplies of it.

CHAPTER IX

WE FEED THE SOIL

THE WORLD of wild vegetation would not continue in existence if Nature had not so arranged affairs that the soil could sustain plant life without man's help. We see its independence of man in the woodland, on the heather moor, in every tangled growth beside the hedge. Why then should we feed the soil in our gardens and on our farms? To get the answer we must look at the places where man has interfered with Nature. He takes away from the garden every fruit and vegetable which it has produced; they all represent plant food extracted mainly from the soil. Watch the cart-loads of corn and hay being led off the fields; the ground they are leaving is the poorer because of their departure. The fat bullock and the fleecy sheep are driven from their pastures; how many stones of beef and mutton have been made out of the grass which has been fed on the meadow soil? Man is continually robbing the earth in order to feed and clothe himself. This cannot go on for ever; he must pay back; he must feed the soil with manures, in order to preserve the fertility of the land.

Naturally, the first thing the cultivator must ascertain in trying to feed plants is the kind of food which they require. It might be possible in some of your schools to carry out an experiment which gives you information about food requirements of plants, but as the directions are rather long, I will place it in the next chapter. It can be proved by this method that the plant must have the chemical elements nitrogen, potassium, magnesium, sulphur, phosphorus, calcium and iron. It also uses much water, which supplies it with hydrogen and oxygen. It breathes as you do, and so gets more oxygen. Then we have seen that it takes carbon from the carbon dioxide of the air (p. 13). Those who have been investigating the food of plants for years have been discovering still other substances which the plant *must* have, though in infinitely small doses. One of them is boron; when peas and beans are growing badly it may be due to the lack of boron in the soil. Manganese is another of these stimulating chemicals. The necessity for traces of copper has been proved recently when land was being reclaimed from peat; the new ground has to be dressed with a copper salt. Iron and magnesium are essential to the existence of chlorophyll.

To give a list of elements is not a sufficient guide, for the plant admits them into its body only when they (most of them) are in combinations which can be dissolved in water. You may refresh your memories from pages 58–63. They suggest to you that 'feeding the soil' is another way of saying 'feeding the bacteria'.

The food which a vast number of the bacteria devour is the fibrous stuff which constitutes decaying leaves, stems etc. It is the basis of the humus of the soil, in all stages of breaking down. You will remember that the result of the activity of these small creatures was chemical compounds of which nitrates are examples. Does it suggest itself to you that the gardener might cut out the bacteria altogether, and put into the soil a sufficiency of the substances which they build up, if he can get them? That is just what some cultivators of the soil think is the best thing to do. Never-ending discussions go on between those who believe in supplying organic manure (humus) for the bacteria to work on, and those who believe in direct application of chemicals. The humus arguments seem to be prevailing. Still a third group argue that the safest plan is to use both. I should place myself with the third. You need not accept the decisions of other people on this point without trying experiments to compare the effects of the two methods of manuring.

The principal form in which organic manure is applied to the garden is the farmyard dung from horses, cattle and pigs, mixed with the straw litter of their stalls. Even before they leave the animal's body the grass blades are partially rotted and ready to be turned into humus. Sometimes the dung is worked into the ground in autumn, sometimes in spring. The type of soil is one factor which decides the date. If it is very loose and sandy there is danger of the food materials being washed down into the subsoil. A soil which is less well supplied with rain, for example in parts of east England, will derive most benefit from dung in autumn. The nature of the crop must also be considered. For the following plants the ground is best manured six months before planting: cabbage, cauliflowers, carrots, beet, onions. Spring manuring is best for potatoes, peas, beans, lettuce, turnips and vegetable marrow.

In some districts it is not easy to get supplies of farmyard manure. The next best is the manure which you can produce in a compost heap. I have already made reference to this (p. 58). Nearly every gardener seems to have some original idea about the making of one. The foundation, of course, is always the same—every bit of vegetable refuse which comes to hand, provided that it is not woody; the twigs and branches go into the bonfire to be turned into wood-ash. There should also be excluded from the compost heap potato haulms and tubers, and the underground parts of turnips and cabbages, all of which may spread diseases.

The heap may either be piled up as a mound, or laid down in a deep trench. If you use a trench you can start filling it in at one end and moving gradually towards the other as your material comes to hand—perhaps over many weeks. The completed manure is drawn upon in the same order. By the surface mound system, you go on piling up the stuff in layers about nine inches thick, on a good-sized foundation, perhaps to a height of four feet. Some people turn it after it has lain for some time. It is essential that the compost material should not be allowed to get dry; neither should it lie water-soaked all the time. Each layer should be trodden down firm, and covered with a few inches of soil.

Various recommendations are made for hastening the rate of decay. There are preparations on the market which are intended to save you the trouble of considering; sulphate of ammonia will serve the purpose quite well; a sprinkling of lime on each layer is an advantage. One authority uses a mixture of sulphate of ammonia (two parts), ground chalk (two parts) and superphosphate of lime (one part); his compost is said to be ready for use in three months. As long a period as nine months is usually allotted to the decomposition. In all cases the succession should be: (1) the layer of plant material, (2) some ammonia sulphate or other aid to decay, (3) a layer of earth, (4) a scattering of lime; then start again with a layer of refuse above this.

It is wasteful to burn leaves which have fallen from trees. They may be dug into the ground in autumn in the same way as manure. Or they may be stacked in heaps to rot down for the leaf-mould which is so valuable for potting plants and other purposes. The value of these leaves depends on the amount and character of the nutritive material which is left in the leaf after the rest is withdrawn into the tree, as happens before the leaf falls. Oak and beech leaves are the best. The leaf mound should be turned over from time to time, and given a slight dressing of sulphate of ammonia.

Hop manure can sometimes be bought for gardens; it supplies organic matter, phosphates, potash and nitrogen. Peat also is sometimes on the market. It has to be treated with bacteria; it adds humus and nitrogen to the soil. Dried blood is sold in small quantities; it gives up its nitrogen very slowly to the soil.

Liquid manure is often a convenient form in which to give both water and food, as for cabbage, lettuce and roses. It is prepared by suspending in a tub of water a bag containing some farmyard manure. It is drawn upon as required, and diluted to a pale brown colour before applying. Soot water is prepared in the same way.

I have already spoken of 'green manuring' (p. 45). Green stuff of any kind put straight into the soil should be kept near the surface, where the bacteria can get all the oxygen they want from the air in the top soil.

We pass on now to consider the rivals of the organic manures—the chemical (sometimes called mineral or artificial) manures. They may be grouped as: (*a*) nitrogenous, (*b*) phosphate, (*c*) potash, (*d*) calcium. These terms give you an idea of their most important constitutents.

One advantage belonging to such manures is that you can select from the list the very one which you think a plant needs as a stimulant at some particular moment of its life, and administer it. For example, if you think a plant needs phosphorus, then you give it phosphates.

On your workroom shelves there should be stocked specimen bottles of the principal chemicals employed in gardening. Each one should be tested to find out how readily it dissolves in cold water. If your school does any pure chemical work, you can carry out other tests under the guidance of your teacher.

We will now examine the manurial groups one by one.

(*a*) **Nitrogenous manures** are intended to feed the plant with nitrogen. Nitrates contain this, and so does any compound in which ammonia appears. The four principal nitrogenous manures are sodium nitrate, potassium nitrate, ammonium sulphate and ammonium phosphate. Soot contains a small amount of nitrogen; it absorbs heat readily; slugs are said to object to it. It is quick-acting, and is helpful to young onions, parsley and seedlings in general. It must not be left exposed to rain before using, and it must be stored for some weeks before use.

Sodium nitrate is the chemical name of 'Chile saltpetre', an impure form of which exists in an immense bed in Chile. Great quantities have been applied to agricultural work since it was discovered there in 1830. It is now manufactured on a large scale by more than one process. In one method, nitrogen from the air is made to combine with oxygen, by passing electricity through air; the result is used for building up nitric acid and then nitrates. Nitrate of soda should be used only on growing crops which are ready to seize on the salt as it diffuses; otherwise it drains away.

Potassium nitrate is 'saltpetre'. For a supply of it we used to depend on certain districts in India where it appears on the soil as a crust a few inches thick. It is now manufactured. It is another easily soluble salt.

Sulphate of ammonia contains more than 20 per cent nitrogen, and in that lies its value. It also furnishes sulphur. It acts quickly in the soil. Phosphate of ammonia provides both nitrogen and phosphorus. It acts rapidly, and is therefore a useful stimulant.

There is a general rule which forms a dependable guide for the gardener—that he should give his plants their nitrogenous food in the early part of their growing season. They require it mainly for building up the body of the plant, in particular, a good working party of leaves. When the flower and fruit stage is reached the prime necessity is for ripening and drying out both wood and fruit. One example of this is the application of nitrate of soda as a top dressing for spring cabbage, and another the use of various nitrogenous manures for fruit trees in spring.

(*b*) **Phosphate manures** act in favour of roots and fruits. The trade supplies them in the form of superphosphates. Bone flour is also sold; it acts slowly in the ground. It is the residue left when bones have been deprived of fat and gelatine, and ground to powder. Here we see the phosphates which were carried away from the fields in the bones of animals being returned to the soil by man. There are other preparations on the market. Basic slag contains phosphates as well as lime; it is waste product from steel works.

(*c*) **Potash manures.** Potassium phosphate is strong and acts quickly. 'Kainit' is sold as an inexpensive potassic manure. Potassium sulphate is a purified form of kainit, much stronger and quicker in action. Wood-ash, which is obtained by making a slow-burning bonfire of woody cuttings, contains quantities of potash. As the potash salts are very soluble, the ash must be kept dry. Potash manures encourage the formation of starch and sugar, and are suitable for plants in their mature stage of growth. Beet and potatoes are both helped by them.

(*d*) **Calcium manures.** Calcium is put into the soil in the form of lime, limestone, or chalk. The necessity for a constant amount of lime can scarcely be exaggerated. In the first place, some lime is needed for building up some of the substance of the plant. Then you have learnt that lime neutralizes acid soils and therefore makes them fit for bacteria to live in. You remember how the colloids of clay soils make them stiff and sticky. The effect of bringing lime into contact with colloids is to cause the very small colloid particles to run together into bigger groups; the soil, as a consequence, becomes more crumbly. You would have seen the haze of colloids clear up very quickly if you had added some lime-water at the close of your experiment on p. 41; the colloidal form would be destroyed, and the larger particles would sink.

Lime destroys some pests. You will learn that, for example, when we study the disease called 'club root' in cabbages.

Some soils are deficient in lime because they have been derived from rocks in which it did not exist. When present, it is liable to be washed down below the usable soil, if it is changed into the soluble form of bicarbonates. Even soil which is lying on the top of chalk rock may contain little lime because it has been leached (washed) out by rain. In the case of farmland, lime is removed in the bones of stock fed on it.

I have already given an opinion on how you may make up your mind about whether or not your garden needs lime. If in doubt, lime it. I may as well give you here a test which is generally quoted for getting an inkling of the soil's lime needs. Half fill a cup with soil. Add a little weak hydrochloric acid. If effervescence takes place, it shows that a certain amount of lime is present. If there is no effervescence, then decidedly you must add lime.

Either powdered limestone or chalk (both carbonates of lime) or lime (calcium oxide) may be used for the garden. Superphosphate of lime is another way of adding lime. Quicklime (calcium oxide) is what is left behind when limestone is heated in a lime-kiln. It is converted into 'slaked' lime by adding a small amount of water to it; and into lime-water by adding a large amount.

In some soils a slight dressing of lime may be given every autumn, and a heavier application every three or four years.

During the course of the Second World War the Ministry of Agruculture issued pamphlets advising the use of a National Universal Fertiliser which was labelled 'Gromore'. Its composition is this: sulphate of ammonia (one part), sulphate of potash (two parts), superphosphate of lime (three parts). You will observe the presence of sulphur, nitrogen (in ammonia), potassium, and calcium oxide.

The Ministry advises a total of forty-two pounds for every three hundred square yards, which you can work out at your own convenience. Part of this is scattered and raked in on the surface. Potatoes receive out of it an extra dressing when planted, and it may be given in August as a top dressing to plants which have to stand the winter. There is a wide field in which you may experiment with 'Gromore'.

CHAPTER X

WATER-CULTURE EXPERIMENT

THIS CHAPTER differs from all others in this book because originally a great part of it was not written for you; it was published many years ago in the *School Science Review*, the Editor of which has very courteously allowed me to use it over again. It contains an account of an experiment in growing plants in solutions which was carried out by the senior girls in a High School placed in the centre of a great city; they enjoyed the advantages of chemical and botanical laboratories, but they had to cope with the disadvantages of city conditions. Many of you in your schools may not be able to conduct an experiment with such exactitude, but you may learn various things from a study of the methods employed. You will note the many precautions adopted, the pains taken to secure accuracy, the patience needed in making observations including many details, regularly during many weeks, the use of tabulation for results, and the practice of making sketches.

Water culture experiments have for their object the determination of the elements essential to the plant as food material, and of the way the plant is affected by the lack of given elements from its diet.

The principle followed is to cultivate plants in water solutions of known chemical constitution; one solution is normal and contains all the elements supposed to be necessary; growth in this is compared with that in a series of other solutions from each of which, in turn, there is omitted a single element. The directions for carrying out the experiment which are set out here were those actually tested in the school laboratory. Quite probably there are equivalents which will prove equally satisfactory.

Culture Solutions

A solution (normal):

Distilled water	1,000 c.c.
Potassium nitrate	1.0 gm.
Magnesium sulphate	0.25 gm.
Ferrous phosphate	0.5 gm.
Calcium sulphate	0.25 gm.
Sodium chloride	0.5 gm.

B solution. *Cut out nitrogen* by substituting potassium chloride for potassium nitrate.

C solution. *Cut out potassium* by substituting calcium nitrate for potassium nitrate.

D solution. *Cut out magnesium* by leaving out magnesium sulphate; there is sulphur left in the calcium sulphate.

E solution. *Cut out sulphur* by using calcium nitrate and magnesium chloride instead of calcium sulphate and magnesium sulphate.

F solution. *Cut out phosphorus* by substituting ferric chloride (a trace) for ferrous phosphate.

G solution. *Cut out calcium* by leaving out calcium sulphate; sulphur remains in the magnesium sulphate.

H solution. *Cut out iron* by substituting calcium phosphate for ferrous phosphate.

I solution. *Sodium* and *chlorine* can be *cut out* together by leaving out sodium chloride.

J solution. *Cut out everything*. Use a control jar of distilled water.

Preparation of Solutions

Prepare, in accordance with the foregoing prescriptions, the solutions which it is intended to test. Be particular to use the purest salts obtainable and to sterilize the vessels used. Use distilled water, of course. Store the solutions—about two litres of each—in stoppered glass bottles. Be careful about labelling, fixing two to each bottle as a precautionary measure.

Preparation of Culture Jars

Use glass jars having a capacity of at least one litre. The type of jars and their fitments here described have been found most satisfactory. The actual vessels were inexpensive stock obtained from the household department of a general store and had been intended for kitchen storage purposes; they possessed ground glass rims, were wide-mouthed, and stood 17 cm. high.

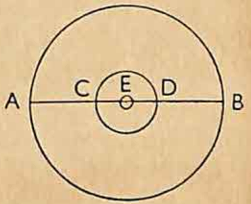


FIG. 15.
DIAGRAM OF GLASS STOPPER
A-B, 8 cm.; *C-D*, 2.5 cm.; *E*, space for plant.

Corks, 1.5 cm. deep and 8 cm. in diameter, were made to order, to fit the jars exactly; they were coated with paraffin wax. From the centre of each cork a circular section, 2.5 cm. (*C—D* in Fig. 15) was cut. From this removable cork a small central core was bored out, leaving a cylindrical cavity for the reception of the slender plant stem. The small cork was cut vertically and diametrically along the line *C—D*; the two halves, when separated, allowing easy insertion of the specimen.

Immediately before setting up the experiment, sterilize the culture bottles by washing them out with dilute sulphuric acid; rinse out thoroughly with distilled water. The corks also should be cleansed. Label each jar as it is filled; attach the chief label as a narrow strip along the lower edge of the jar where it will not interfere with viewing or photographing the growth within the jar; for safety, an additional identification mark may be fixed on the base of the jar.

Each jar is enclosed in a cover which will entirely exclude the light. This is made of a two-fold thickness of the heaviest quality of black Italian cloth. Cut a strip of this of such dimensions that, when doubled, and sewn end to end to form a bottomless bag, it fits neatly round the jar, and is deep enough to reach from the base of the vessel well over the cork. Through a slot at the top run a double drawstring. Attach to the cover a label which corresponds with the label on the jar; any particular culture can then be selected for inspection without removing other covers.

Selection of Plant Material

Strong seedlings or slender herbaceous cuttings may be used—the latter more suitable for school conditions. Cuttings of *Tradescantia* have been found excellent; but various other plants of quick growth will serve. Seedlings should have the minimum of food reserve attached to them; wheat is preferable to maize; sunflower may be tried.

The utmost care must be taken that the specimens chosen are equal in size and vigour and in leaf area; variegated leaves of *Tradescantia* must not be included. Before estimating leaf-surface, remove any lower leaves which would hinder fitting into the jar. If the plants from which cuttings are taken have not been reared in school, those obtained from tradesmen should be kept under observation for a week or so; they have been known to fall off badly owing to transference from greenhouse temperatures. Seedlings should be grown in sand or on damp muslin, and the roots gently washed clean before putting them into the solutions. The axis of the plant must not fit so tightly into the cork that there is no room for growth in thickness.

Take the branch cuttings with care; make a sharp, clean cut; by cutting just below a node, root-formation from the node is encouraged. An additional precaution may be taken if thought desirable: to make sure that the conducting tissue of the stem does not get air-blocked, perform the cutting under water. All operations, especially with seedlings, must be carried out as quickly and delicately as possible.

April, in a northern city, has been found to be the most suitable month in which to set up culture experiments. Conditions of light and temperature will be guides to this.

Setting up the Culture

Everything being in readiness, fill each of the labelled jars with its appropriate solution. The jars must not be filled quite to the top; the amount of air-filled space left above the liquid cannot be exactly specified since it depends on the size of the plant used; it is an advantage to have as much air enclosed as possible.

Prepare the cuttings, or seedlings, as already specified; insert them between the halves of the smaller cork; adjust them so that the seedling roots, or the lowest node of the cutting, is well covered by the liquid. Slip on the cloth cover from the base of the jar upwards; use the draw-strings to draw it up rather loosely round the plant stem. It can be slipped off very easily when the contents of the jar are to be examined. Sometimes a little cotton wool is packed round the stem.

After-care of Culture

Place the jars side by side in positions such that they get similar treatment in the matters of light, heat, etc.; the window ledges in the school laboratory have proved quite suitable, the south windows being avoided during the first few days.

Directions are usually given for aerating and for renewing the culture solutions. For example, the cork may be pierced to allow of the insertion of a glass tube through which air can be blown into the liquid, the cork stopper being meanwhile raised a little. Some workers change the solution once or more often. For school experiments, which are not generally carried on as long as those in more advanced work but are intended to demonstrate principles of cultural needs, it has not been found necessary to take either of these steps. For the replenishing of the air supply to the roots, the space above the solution seems to yield a sufficient supply by diffusion. Again, if plenty of the culture solution is used (the litre appears to be enough for a moderate-sized branch), there is no need to change it completely. As the level in the jar is lowered owing to absorption and transpiration, additional solution from the stock jar can be added as is required. One of the aims kept to the front in the experiment should be to disturb the plants as little as possible.

Records

These, one need not insist, must be full and exact, made at regular intervals, even if results are negative. Among points to be noted are: growth in length of shoot, number and size of leaves, colour, buds, general strength, variations in rate of growth throughout period of observation. It is very important to watch the progress of root development; this is made easy by the facility with which the cloth covering can be removed and replaced.

For the particular experiment some of the results of which are given here, the solutions used and the methods adopted were in conformity with the directions advocated in the preceding paragraphs. The culture jars were kept on the window ledges of the laboratory, facing south; the jars were turned daily to avoid one-sided illumination. The cultures were set up on April 21; on May 19 more solution was added to the jars to bring up to the first level; graphic records (photographs and drawings) were made on May 21 and 22; final photographs were made on June 24, and the general observations were closed. Supplementary notes were made on June 30. All records were made by the girls under the supervision of a teacher.

One fact which must be very carefully noticed in collating results with specific solutions is that the omission of one element often involves an increase in the amount of some other element. Thus:

Removal of:	*Contingent change:*
B. nitrogen	more chlorine
C. potassium	more calcium
D. magnesium	less sulphur
E. sulphur	more nitrogen and chlorine
F. phosphorus,	more chlorine
G. calcium	less sulphur
H. iron	more calcium

Observations on Tradescantia

Axial Growth, extent of branching, leafage. These varied to an extreme degree. At the conclusion of the experiment, the plant in normal solution presented the best appearance of general health; the plant lacking iron, however, though its leaves were palest yellow, was by far the most profusely branched and leafy (sixteen axes in non-iron, as compared with four axes in the normal).

The direction of growth on the main axis is worth noting; it varies considerably. Observation of a control *Tradescantia* plant growing normally in a pot shows that each new shoot grows vertically for a time, but, when it attains a certain length, falls over, through the drag of its own weight, and assumes a horizontal position; a curvature develops in course of time and the tip resumes its upward path of growth. The photographs taken after a month's growth showed the following: in the normal solution and in those lacking phosphorus, nitrogen and calcium, the main axis is nearly upright; in solutions lacking iron, sulphur, and magnesium, the main axis (growth quite strong) has bent into the horizontal at the first node above the jar, its branches growing upwards. Only in one case had the precise date of bending been noted. A drawing was made on May 21 of the non-magnesium plant, which shows the main axis only slightly divergent from the vertical; on May 22 the girl who drew it noticed that it had fallen over, and on that day it was photographed and the horizontality recorded. Branches in the pot plant apparently fall over earlier, before branching begins.

Leaves. The principal difference in these was in the absence of chlorophyll in the new leaves on the plant deprived of iron. Minor differences are recorded in the tables.

Roots. Striking contrasts in root development were apparent at an early stage. In the normal solution, the first roots grew downwards and a fairly bushy group was present on May 21; root-hairs on an area near the tip in each case. By far the most abundant root-growth belonged to the plants deprived of iron or of sulphur; in the absence of iron, the roots were astonishing—very long, with numerous side-shoots, covered throughout their length with root-hairs. That of the plants without calcium or magnesium was extremely scanty; in the former the roots struck out horizontally, in the latter they took a steep slant downwards. When nitrogen was absent, the roots were poor, only slightly branched, and dark brown. In distilled water, roots never progressed beyond the stage of a small circlet of tips protruding at the node.

It is rather surprising that the information given about water-culture experiments generally ignores the behaviour of roots in response to food changes.

Note. Special reference must be made to the non-potassium culture. It made practically no progress; not a single root developed in three weeks.

A second cutting was fixed up on May 22, to test whether accidental injury was responsible for the first failure. On the second day, the branch looked soft and weak. On June 1 no roots were showing and the stem was decaying. There was no further development. On June 2 three other cuttings were fixed up; two were kept in the laboratory and behaved as their predecessors had done. The third was kept in a rather warmer, less well-lit room. It flourished quite well; on June 24, it possessed a good system of roots, and its axis was upright and strong; five new leaves had unfolded and three branches were developing; the leaves were normal and healthy. On July 2 the axis bent over at the first free node.

(Here, in the original account, followed four tables giving details in full of the observations made; they are too lengthy to reproduce here, but the final observations are reproduced.)

Special Record of Observations

Final observations made on *Tradescantia*; June 30

A. Normal	Definitely the healthiest plant. *Shoot*. Continued healthy growth of main axis and branches. *Roots*. Slightly brown, but healthy and well developed. Plant as a whole shows few signs of withering.
B. Lacking nitrogen	*Shoot*. Some growth at tip of main axis but no further growth of branches. Branch growth poor, apparent withering. *Roots*. Arrested growth—especially branch-roots, which appear withered.
C. Lacking potassium (Set up June 2, see previous note)	*Shoot*. Healthy growth of main axis and branches. *Roots*. Healthy and well developed.
D. Lacking magnesium	*Shoot*. Some growth at tip of main axis. Branch growth only fair. *Roots*. No change.

E. Lacking sulphur	*Shoot*. Only extreme tip healthy. Majority of leaves on main axis withered, black or very dark brown, in contrast to lighter brown of other faded leaves. Leaves generally small, rather long and narrow in shape, deviation from typical form; withering leaves. *Roots*. Continued branching.
F. Lacking phosphorus	*Shoot*. Latter half healthy, branch growth healthy. *Roots*. Good development.
G. Lacking calcium	*Shoot*. No further development. Branch growth poor. *Roots*. Slightly longer, but black and still horizontal.
H. Lacking iron	*Shoot*. Branch growth much greater than axis. Newest growth yellowish white. Free branching continued as before. *Roots*. Most abundant. Marked development of root-hairs.

A daily weather chart was compiled; the details are not of sufficient importance to reproduce. The days were moderately warm, with variable sunshine and many dull hours; no extremes of temperature.

The main object of the experiment was to note and record facts. Warnings were given against drawing conclusions from one set of experimental results.

CHAPTER XI

REARING SEEDLINGS

REARING seedlings is like tending children in the first years of their lives. To do that rightly needs some knowledge of the small bodies. Bring out, look over, and compare the seeds which are to go into your garden plot—turnip, onion, beans, etc. Some are no bigger than grains of dust; some quite substantial; what does this difference signify?

Long before you set about your spring sowings in the garden you may be experimenting in the schoolroom or at home, finding out many facts which will guide you in garden work. The most convenient seed for you to start with is the broad bean. At every stage in these experiments of yours you must make careful sketches; the series of them should present you with a picture of the seedling's history.

Consider the outer surface of the bean, which is drier and more shrunken than if it had been left in the ground. Allow some beans to soak for a few hours; first, the coats stretch and become baggy; then, the inside also swells and fills them out. Take one out and dry it; squeeze it gently and water will ooze out of it at a point near the brown scar. A hand lens will disclose a tiny hole here, a most important hole (the botanist's **micropyle**). Slit the seed-coat across into two parts and remove them. There are revealed two thick flat structures, or lobes, joined to a projecting conical part at one end. Remove one lobe *very* carefully. There, lies a delicate prolongation of the cone; a hand lens shows that it consists of a number of thin pieces. What the nature of these various parts is you must determine by a set of easy experiments. You will find out how readily the seeds can be got to grow in such a manner that you can watch them doing it.

You may use pots or boxes, some filled with moss, sawdust or soil; or corked bottles; or even layers of wet flannel. In the bottle method you pin the bean through one of the lobes to the under surface of a cork which closes a wide-mouthed glass jar; the jar contains water, and the space above the water will be filled with moist air. You can make for yourselves wooden boxes by means of which you can view underground growth. Make one side of the box of a sheet of glass, and let that glass slope inwards at the base. The seeds will be placed close up to the glass.

Make clear to yourself always what question you want each experiment to answer for you. Take the bean in the bottle. You will soon see something beginning to push outwards at the conical point and at last breaking through. This tip goes on lengthening, and turns downward. You soon recognize it as a root with its root-hairs (Fig. 16). In the meantime, the delicate morsels of tissue have been unfolding, and appear as the top bud of the stem joined to the root; they strike upwards. There

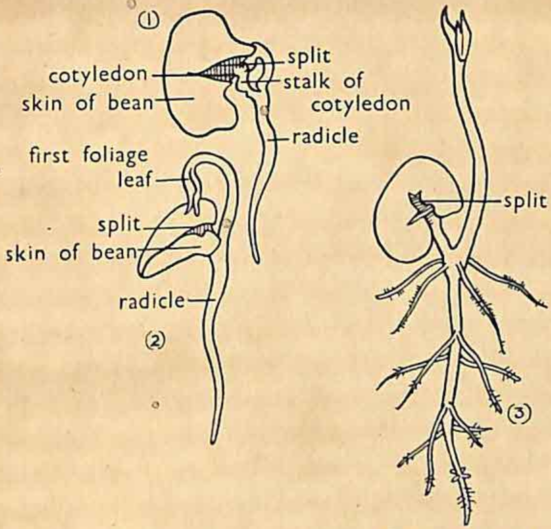


FIG. 16. THREE STAGES IN THE GROWTH OF A SEEDLING OF A BROAD BEAN

has been a baby bean plant, an **embryo,** tucked away within the seed. What else do you learn? That a good deal of growth can go on without soil; give the plant at this stage sufficient moisture and it can manage quite well.

Follow the behaviour of the beans in the moss in your glass-fronted box. Put a stone directly underneath one of them, and see what the root will do. On the surface of the soil or moss, lay on its side a seedling the root of which has already grown an inch or more. See that it is kept moist by covering it with a jar; keep all in a warm dark place for two days. If your root tip has not been injured, it will have buried itself in the soil; the tip of the shoot will have turned upwards. Here you are faced with the problem which I put before you on the first pages which I wrote for you; is there an answer here? I am afraid not.

By growing seeds (*a*) in wet sawdust, (*b*) in dry sawdust, you can prove the necessity for water in germination. Plant beans at different, marked, levels in flower-pots and compare the length of time taken to appear at the surface in all cases. Try covering a pot with a layer of 'Plasticine' or stiff clay, to get an idea of the power of the growing shoot to pierce its way through obstacles.

Take up plants which have developed some leaves in pots or in the ground and notice how the seed lobes have shrivelled and emptied of their contents. Replace a germinated seed from which you have removed one lobe; another, from which both lobes have been taken. In the first case, further growth is poor; in the second, development is completely checked. Is this proof that the lobes have been feeding the young plant? Probably it explains its independence of soil at first. If so, it just means that old mother bean plant had fixed up the infant which she was leaving behind her with a couple of feeding-bottles. As a matter of fact, she had spent the best part of her life filling up those bottles. What did she put into them? Touch the broken surface of one of them with a little iodine solution, and you find that it turns dark blue. You get the same colour by applying iodine to starch; so you may reason that starch forms some part of the food for the baby beans. There is other, stronger, food as well, as you will see in the next chapter.

For comparison with the broad bean you must grow some dwarf French beans. Their food-lobes behave in quite a different way, for they come aboveground and turn green. They very plainly are leaves. So are the same organs in the broad bean, though they never emerge from the soil. These first leaves of the embryo are known as **seed leaves**, or **cotyledons**. In most plants they turn green; they wither away early, and are succeeded by the true foliage leaves which the gardener often speaks of as 'rough' leaves.

We will now apply to your gardening what has been learnt by experimenting. Here you will have to act as nurses to baby plants of many families. Their beds must be scientifically prepared, some of them tucked away in the rows where they are to spend their lives; some will start in a 'nursery' bed, and be transplanted to their permanent quarters. In both cases the first preparation of the soil is the same. First of all, long before the seeds go in, it must be well dug, and, if necessary, manured. The next object is to secure a fine surface 'tilth', that is, friable, crumbly soil, for the seed must have plenty of air for its germination. So level the soil and then tread it all over very firmly; after that rake it lightly. No stones are left, of course.

You will be given on the spot your instructions for laying out the ground; you will do everything in neat and methodical style with line, pegs, and measuring rod to mark out drills.

You have to decide the depth at which the seed is to be placed. You have the guide already—the size of the seed, mainly. In tiny seeds there can be scarcely any stock of food in the cotyledons, just enough to send them above the ground, where at once they have to take up the job of providing food in partnership with the first root. If they were buried deeply they would never reach the surface in time. The reverse is true of large seeds which contain enough food to last for some time.

Sow seeds as thinly as possible, in order that every individual may have a fair chance of light and air and water from the start. Otherwise you will have weakly, 'leggy' plants. Another reason for this is that the disturbance caused by thinning out should be lessened as much as possible. Cover the seeds with fine soil and rake over gently. If the weather is dry the bed should be lightly watered an hour or two before sowing. The bed must never be allowed to get dry; you have learnt why.

As I have already pointed out (p. 51), it is useless to put in your seeds when the ground is too cold. You may try how far cloches will help in bringing forward seedlings.

Having done all you can for the welfare of the small babes, you watch every day for signs that they are alive and thriving. Various plants have their individual ways of breaking through the soil—some as spear-points, some as rounded arches (Fig. 17). This is what I once wrote after watching the waking up of bean seedlings: 'The genuine gardener loves his seed beds best of all. One day he sees them trim and lifeless; next morning he knows that living things are stirring there; the level is broken by

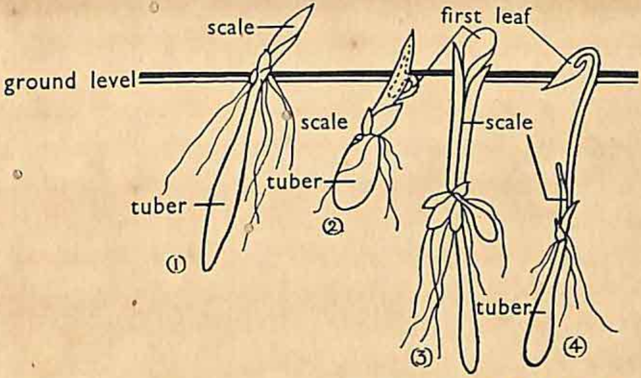


FIG. 17. HOW LEAVES EMERGE IN THE LESSER CELANDINE
1, 'spear' bud; 2, leaf bending to withdraw.

narrow cracks and tiny mounds; something possessed of energy and apparently at no loss how to direct it is elbowing the soil aside and thrusting itself forth. It makes one want to sit down and see what happens. The rounded arches which lift themselves in the bean-bed take on a tinge of green almost before one has time to think of them as yellow. Up they come, till you find that each is a little curved stem; one end of this stays fixed, the other drags itself free from the soil and shows its leaf-clothed tip. . . . The stem gradually straightens; the green deepens; the leaves are spread to the sunshine.'

Seedlings must be tended regularly and judiciously. They must never be allowed to lack water, but they must not be over-watered. If crowded together, with insufficient air and too much moisture, they are liable to 'damp off'. These are conditions which favour a fungus which eats into and weakens the stems until they fall over. It is recommended, however, to spray with water several times a day turnips growing in the open, up to the time when the rough leaves take over duty from the seed-leaves. The moisture, plus a dusting with soot or even dust, will discourage the turnip fly from settling.

Thin your rows of seedlings as soon as the first rough leaves are acting, and thin them more than once.

When you are transplanting, act upon all that you learnt about young roots and root-hairs. Have the holes prepared beforehand. Take time to lift every seedling with a ball of soil round its roots; a broad old kitchen knife and an iron spoon make fine 'lifters'. Press the soil close round the rootlets, leaving no spaces. Water the seed-bed the night before transplanting, and water the seedlings after settling them in.

CHAPTER XII

WHAT SHOULD YOU GROW?

PROBABLY neither the school garden nor your garden of the future will be large enough to grow even a little of every kind of vegetable. One day in your classroom you must have a grand discussion to argue out the merits of vegetables as foods. The people from the cookery class must make themselves heard. Which vegetables supply the best food is the first question. Also, which vegetables are at their best when got straight from the garden rather than from a shop. I can hear someone say, 'I want lettuces fresh and crisp'; another, 'New potatoes have the best flavour when they pass direct from the ground to the pot'; another, 'Green peas spoil in the shop'. And so on.

I will give you a few, a very few, particulars about the chemical food value of several of our vegetables. I must begin by referring briefly to the kinds of food needed to keep us strong and healthy. There are five classes of them. (*a*) **Sugars, starches, fats,** and **oils** are specially used in keeping you warm and giving you that energy which keeps your mind and your muscles in activity. They consist of the elements carbon, hydrogen and oxygen. (*b*) The **proteins** are of the highest importance. In addition to the elements just mentioned they contain nitrogen; some sulphur and phosphorus are also present. These foods are able not only to furnish heat and energy but they constitute the material for building up the tissues of the body. The vegetable proteins occur in peas and beans, in cereals, and, a little, in potatoes. They are inferior in quality to the animal proteins of meat, eggs and milk. (*c*) **Mineral salts** are needed in small quantities; common salt is the principal one. (*d*) **Water.** (*e*) **Vitamins.**

I have already given you the test for ascertaining the presence of starch. You may apply the following for proteins. Warm the substance suspected along with a little nitric acid. If protein is present the mixture turns yellow. If you now add ammonia, it turns orange.

Until a few years ago nobody knew that vitamins existed. It is now proved that though they give no heat, no energy, no material for tissue-making, yet they are vitally essential. In ways still mysterious they keep going all the processes within our bodies. Scientists have devoted much labour to them, and have identified a large number of them, judging them by their actions. They know the chemical make-up of some of them, and can actually manufacture some. Vitamins are formed mainly in green vegetables under the influence of sunlight. I need give you here only the best known. They are named from the letters of the alphabet.

Vitamin A. This is necessary for the growth of the body, and protects us from some infectious diseases. It enables us to see better in faint light. It originates in spinach, cabbage and the red colouring matter of carrots and tomatoes. Animals get it from plants and store it in the liver and fats.

Vitamins B_1 and B_2 are needed for healthy nerves. They exist in the embryo part of cereal seeds, but they have been removed from white wheaten flour. There are other vitamins in this *B* group.

Vitamin C. The absence of this from food leads to the disease of scurvy and other skin troubles. The richest source of it is black currants, and after these rank oranges, lemons, tomatoes, swede turnips and raw cabbage. Parsley, sprouts, spinach, cauliflower, are other makers of it. Lettuce is low in vitamin *C.*

Vitamin D. Food poverty in this causes rickets, other bone troubles and poor teeth. It is obtained mainly from animal fats and fish oils. Cabbage, carrots and potatoes contain none of it.

The comparative values of some of the vegetables as foods is a guide to our choice of them for cultivation. Here are a few examples.

The proportions of food-stuffs in the *potato* are:

Water	76 per cent
Protein	2 per cent
Starch	20.6 per cent
Mineral salts	1 per cent

Vitamin *C* is distributed throughout the tubers in small quantities.

We find in *peas* and *beans* these proportions:

Protein	23·7 per cent
Starch	49·3 per cent
Mineral salts	3·1 per cent

In the germinating condition they contain *C* and *A* vitamins; in the dried condition, some vitamin *B*.

Cabbage contains three vitamins, and its value as food depends chiefly on this fact. Vitamin *C* is liable to be destroyed in cooking. The best method is to shred the cabbage, plunge it into a minimum amount of boiling water, and cook it fast with the lid on the pan in order to lessen the amount of oxygen which gets access to it. Another merit of cabbage and its relations is that they give a supply of green vegetables throughout the year.

Carrots contain a valuable percentage of glucose or grape sugar. The red colouring matter contains the basis of vitamin A, the formation of which is completed in the animal body.

Turnips. The food value of these for man is low; they contain a great bulk of water. They are a valuable field crop as winter feed for cattle and sheep. The juice of swede turnips is particularly rich in vitamin *C*. You may see them being fed to lambing sheep in early spring.

Onions. The storage material in onions is sugar; there is no starch.

Parsnips are a very valuable food. They contain a high percentage of nitrogen, nearly twice as much as there is in carrots and beet.

Beet. The food substance here is sucrose or cane sugar. The white beet is cultivated on the field scale to obtain sugar on a commercial scale.

Salad vegetables in general deserve a place in the garden because of the mineral salts and vitamins which they contain.

If the school garden is spacious enough, a corner ought to be reserved as a small garden of herbs, varied enough to tempt the school cookery class to experiment with the less common flavourings. Here are some plants to include.

First of all there are the four *fines herbes* which French cooks use in their omelets and many other dishes—parsley, chives, tarragon and chervil.

Parsley you know well; it is a biennial; if you sow a crop very early every spring it will be ready for autumn use, and with a little protection it should weather the winter and be of use into the summer months, when it will flower. It takes a long time to germinate. Thin it out repeatedly until the plants are at least six inches apart; handsome foliage may then be expected. It likes soot and lime as stimulants.

Chives are used as a mild substitute for onions. They are easily grown; they may be propagated by dividing the clumps in autumn or spring. Cut the leaves when young and tender; they are good with mashed potatoes.

Tarragon leaves are used for flavouring vinegar; the cook might also try putting a sprig inside a chicken for cooking. The bushy plants require about two feet of space round them; they thrive best in well-drained soil. They are propagated by cuttings or by division of the clumps.

Chervil is an annual plant, the fresh green leaves of which are used for soups and salads. It should be sown at monthly intervals from March to October.

Mint is universally well known. It is a perennial, and you might investigate its underground method of spreading and giving rise to new plants by its **rhizomes,** or buried stem-shoots.

Sage is a little shrub which you can rear from cuttings or from seed, renewing your beds every four years. It likes a light soil with some lime.

Thyme is a hardy perennial which needs plenty of lime and sunshine. Its propagation will give practice in dividing plants or making cuttings.

There are two kinds of **marjoram** in cultivation, both treated as annuals. Pot marjoram has leaves of reddish tinge; sweet or knotted marjoram is a low bushy plant.

Sweet basil (much used in France) is a tender annual, to be raised from seed sown in late March, under glass. It combines well with tomatoes.

Summer savory (an annual) and **winter savory** (a bushy perennial) are both grown.

Sorrel is used in France for soups, stews, etc.; it may take the place of spinach, and may be added to salads. It is propagated by the division of plants. The younger leaves are those used.

Bergamot, with its strongly sweet-scented oil, may be used in salads.

In fair-sized shrubs the garden should show **rosemary,** which, along with **lavender,** is a good 'bee-plant'. A sprig of rosemary put into the pot with roasting meat gives it a delicious flavour.

Mint, sage, marjoram, thyme and parsley may all be dried and stored for winter use; the cookery class should see to that. The plants are gathered when in perfect condition, hung up in bunches to dry (in sunshine if possible); then the leaves are powdered and stored.

CHAPTER XIII

POTATOES

WHAT IS a potato? It grows underground, but it is not merely for that reason a root. Try to make the acquaintance of potatoes in their home in the soil, in their connections with the plant which bore them.

You will find them in various sizes growing at the ends of structures which are long thin branches rising from a parent stem. The potato is really the tip of an underground branch stem which has stopped growing in length, and is thickening gradually into a roomy storehouse for the food sent down from the factories in the green leaves. Such an underground storage organ is called a **stem tuber.** The potato plant has adopted this plan for giving a start to a new generation without having recourse to seed production, although it also produces seeds. The mass of the potato is the stock which is to last the new plant until its own new leaves can support it. You learnt in a previous lesson that it consists mainly of starch. Have you ever seen little potato tubers growing on stems above-ground? They are greenish and situated in the angles between leaf and stem, just where you expect a branch to grow. One often sees reports of them.

You may have an opportunity of comparing a potato with a Jerusalem artichoke, which is more

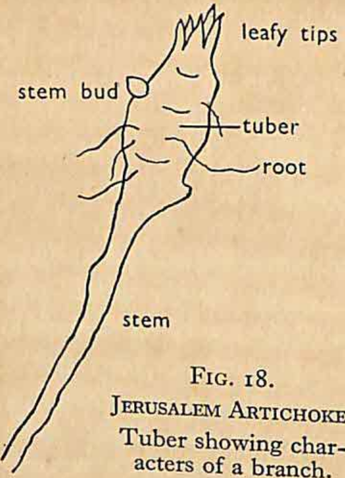


Fig. 18.
Jerusalem Artichoke
Tuber showing characters of a branch.

irregular in shape. Occasionally you come across a young specimen which shows very clearly that it is a branch, like the one which I have drawn for you (Fig. 18). In this there are half-developed leaves appearing ready to form a bud at the apex.

Each one of you must make a careful inspection of a potato tuber; smooth, kidney-shaped specimens are the most suitable. Miss none of the following points: the small depressions bordered on one side by a slight, crescent-shaped ridge; the small growths lying within these hollows; the more crowded arrangement of them towards one end of the tuber. The gardener calls this end the 'rose', and the shallow pits, 'eyes'.

You can easily find out the use of the skin to a potato. Take two tubers, one larger than the other. Peel the larger one, and reduce it to exactly the weight of the other. Balance them one on each pan of weighing-scales. Leave them for some hours. You will find that the peeled potato has grown lighter owing to the loss of water.

The grower of potatoes often starts his task weeks before he could venture to put his 'sets' into the ground. He arranges them, 'rose' end uppermost, in trays; he chooses for them an airy place, in good light, and protected from frost. You must follow his example. You must, indeed, do more, for you want to learn by experimenting. Place a second lot of tubers in a quite dark cupboard, and a third in half-light. In a short time the little bodies within the 'eyes' begin to sprout into the beginning of branches, showing that they have been buds, whilst the ridges were bits of leaves which had never developed. This is a proof that the tuber itself is a branch stem.

Compare together the behaviour of the shoots on your three lots of sets. Those grown in light will be short and sturdy at a time when those kept in darkness have become lanky and pale-coloured. The tubers grown in semi-light will be intermediate between these two in appearance. It seems to follow from this that light actually prevents stems from growing in length quickly. We shall have chances of trying out this theory on other plants.

As the sprouts grow, the tuber shrivels. That means that the new generation has already begun to use up the store of starch provided for it by the old generation.

For planting out you will select tubers bearing strong, short sprouts, and you may remove all but two or three of these in order to concentrate on strong growth. You gain in various ways by giving your potatoes a start indoors. You make sure that they do sprout; you can control their first growth, and they can be saved from frost, yet earlier potatoes can be raised.

The ground intended for the potato crop must be dug deeply in autumn. In spring you draw your furrows, making them run north and south, to ensure that they get the benefit of the strongest sunshine. A generous quantity of farmyard manure (or compost) is placed at the bottom of the furrow. As the nitrogen from this manure is not released for action very readily, it may be supplemented by a little 'Gromore'; you remember that it is in its first growth that the plant demands most nitrogen. Do not lay your sets directly on the raw manure, but with a sprinkling of earth in between them; there is then less risk of rotting. If the sets are large, you may divide them into two or three, always taking care that each piece contains sprouted eyes. If you are using unsprouted tubers, be sure that you place the 'rose' end uppermost. Cover in the furrows up to ground-level.

As the potato is readily injured by frost, it is unwise to plant too early; the date will depend partly on the locality. The ancestors of our potatoes were brought from much warmer climates in southern Chile in South America, which accounts for their being half-hardy. They had been cultivated in various parts of South America long before they were introduced into Europe towards the end of the sixteenth century. Keep a look-out for the appearance of the first leaves, and give them some kind of protection if you get any warnings on the wireless or in the newspapers about frost. Draw the soil up on each side over the young plants; repeat as often as they are threatened.

It is customary to draw up quite substantial ridges round the potatoes as they grow up, leaving furrows between. The object of this is to keep the new tubers well buried in the soil. If one of these chances to get uncovered it very quickly turns green —naturally, seeing that it is a young branch stem. You may learn from this, if you have not learnt it before, that the development of chlorophyll is associated with light (p. 11).

It may add to the interest of your gardening to hear about new methods which others are trying, and to give them a trial yourself. Here is an example. One experimenter maintains that it is a waste of labour to 'earth up' potatoes as I have mentioned. He leaves the surface flat, and considers that he gets quite as good results in every way. Try that plan, setting out two or more rows which you can compare together with precision.

I have tried a variation on the practice of leaving the ground level after the sets have been planted and earthing up a ridge when the shoots appear. I made the planting-furrow a great deal deeper than usual, but covered up the sets with the usual depth of soil. This meant that every row of potatoes lay in a furrow. When the young shoots appeared they were afforded some protection from cold winds by the sides of the furrows, and it was easy to give them a covering if frost threatened. As they grew up the soil was by degrees drawn down close to and over them. As growth progressed, the furrow was filled in level, and later on a slight ridge might be piled over it. The tubers were well buried beyond reach of light. The resultant crops were excellent, and no tubers were lost by exposure.

The following innovation is more startling. It was developed during the Second World War, to save space when exporting 'seed' potatoes to other countries. The experiments were begun at Kew in 1943. Instead of planting a whole tuber, or the better part of one, nothing more than a 'chip' of potato skin, which must include an eye, was placed in the ground. For export, slices half an inch thick were cut and were dried for a month. A private grower tried the plan with fresh, sprouted sets. I will give his details of results. He planted ¾ ounce (17 sets) of the chips, on May 10, nearly four weeks later than he had put in his regular crop; they were placed four inches deep, twelve inches apart, in unmanured soil, just forked over. No fertilizer was given at any stage. Every 'chip-bud' developed. The crop was dug up on August 2; 42 pounds were gathered from the ¾ ounce of seed potato. This was compared with the yield of 36½ pounds got from 17 plants of the main crop raised at the same time. I tried this experiment once myself—half a row from 'chips', the other half from whole tubers, other conditions being made exactly the same for all. The 'chips' were a failure, both as regards rate of growth and amount of yield. Would you like to find out what would happen in your garden if you tried 'chips'?

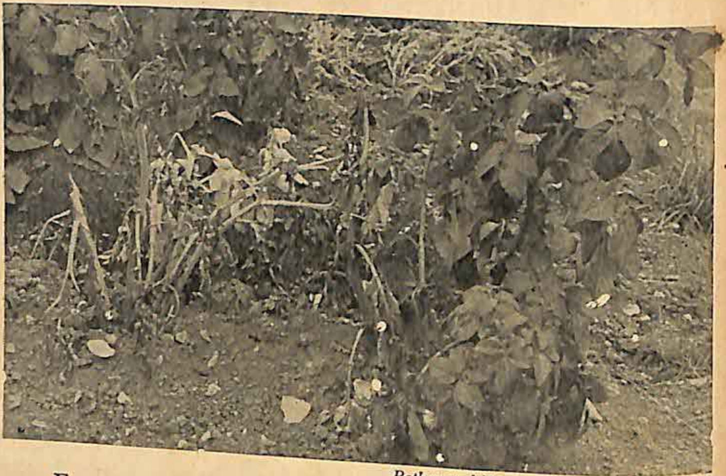
Still another venture you may make. Plant a row of potatoes between two rows of peas, and see what results. The explanation will appear on p. 124.

Potatoes are liable to many diseases. Some of them are epidemic, and have been responsible for tragic failures of this valuable crop. The disease of **scab** or **wart,** is caused by a fungus. Some forms of it remain on the surface of the tuber; others penetrate and cause rot. It may be due to lack of humus in the soil. Immune varieties should be sought for.

Much more dreaded is late **blight,** the potato disease. Early varieties usually escape it, for its season does not begin until the middle of July. It is at its worst when the atmosphere is damp and humid and in shut-in situations. A fungus is the mischief-maker here again, one of those lowly plants which reproduce by means of spores instead of seeds. The spores are very light and are carried about by wind. The first signs of an attack appear in the leaves, which become lifeless, blotched and shrivelled. Soon the spores bred there are falling in showers on the ground, where they proceed to enter the tubers and multiply there. No tuber showing the least sign of infection should be kept; the disease grows worse as they lie in store. To lessen risks the haulms should be cut off before the crop is lifted. Whilst it is growing it may be sprayed with Bordeaux mixture (copper sulphate and washing soda). But as far as possible choose varieties guaranteed immune from blight.

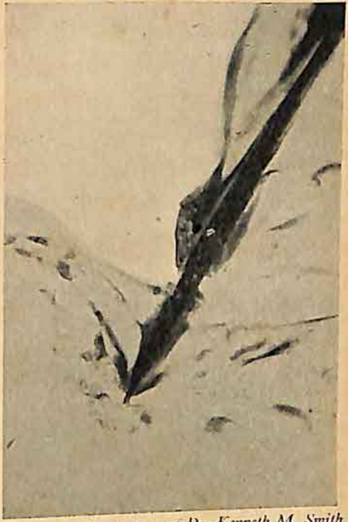
The third kind of disease which I have to mention belongs to a class which is most difficult to track down, one which afflicts many plants, and which spreads with great rapidity. It is the class of **virus diseases**, which, unfortunately, are on the increase in all countries. You, as gardeners, have to keep watch for them in order to check them as soon as possible. Examine frequently the haulms of your potatoes (Fig. 19).

There is a possibility of quite a number of virus diseases attacking potatoes. The commonest of all may be recognized by the mottled colour ('mosaic') of the leaves, the edges of which may also be slightly crinkled. A second, most severe illness, is indicated by dark green streaks and the down-drop of the leaf as it dies. **Leaf-roll** is one of the very harmful diseases in farm crops; the leaves are rolled inwards. If you find any of these symptoms on your potatoes, then up the whole plant must come and go into the fire.



Rothamsted Experimental Station, Harpenden

FIG. 19. VIRUS DISEASE (LEAF-DROP STREAK) OF POTATO
Left, disease in advanced stage; right, healthy plant.



By courtesy of Dr. Kenneth M. Smith

FIG. 20. HOW A SAP-SUCKING INSECT FEEDS.

Stylets are in the act of penetrating the leaf surface.

The symptoms of the virus diseases are unmistakable; but no one yet can tell you the nature of the cause of them. It may be a living organism, or it may be a chemical change of some kind. What we do know for certain is that the infection is carried from plant to plant mainly by those pestilent little 'green flies' (**aphides**) (Figs. 20 and 21). They drive their sharp sucking organs (stylets) down into an infected plant, and draw up the infection along with the sap. Then they make a short flight to another plant, which may be healthy. As their probe goes deep into that it carries with it a quantity of saliva from their mouths, and in this the virus poison travels into a new victim. The poison spreads slowly but inevitably into every part of the plant. Even people who come into contact with infected plants may act as carriers of the disease.

Virus diseases are becoming very common on all kinds of plants. Among the garden victims are raspberries ('mosaic' disease), strawberries, black-currants, tomatoes, peas, cauliflowers, tulips, violets. Who knows how many others will fall to them? So virus-free in varying degrees. They are grown in Scotland in districts in which winter conditions are too severe for the survival of the aphis which chiefly infects potatoes.

The **Colorado beetle** is a foreign enemy which authorities are always anxious to keep out of their country (Fig. 22). There were epidemic outbreaks in 1945 in some counties in south-east England, and stray specimens were found during the next few years. During 1948 the Colorado plague reached epidemic proportions in the countries of central western Europe, and many beetles were found in south-east England; they had travelled in cargoes of fruit and vegetables from France and Belgium. Since then the plague has become more and more serious. It has been spreading northwards in Holland and making its way into Denmark. It is like an invading army, and in 1950 the countries concerned are setting up a combined body of experts to find out the best means of fighting it back. Britain has to do her share, for even the sea gives her little protection. Vigilant watch is kept by those who handle Continental cargoes,

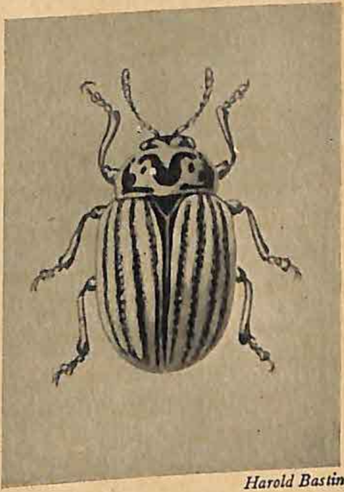
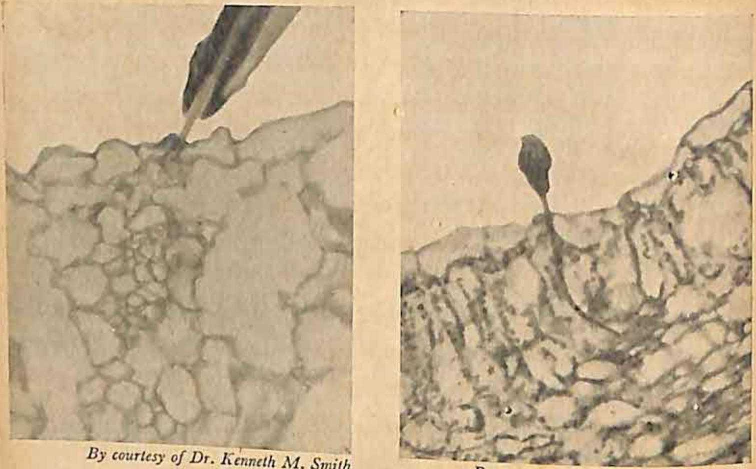

Harold Bastin

FIG. 22. COLORADO BEETLE



By courtesy of Dr. Kenneth M. Smith

By courtesy of Dr. Kenneth M. Smith

FIG. 21. STYLETS OF AN APHIS CARRIER OF A VIRUS DISEASE ENTERING A POTATO LEAF

Left, stylet about to enter; right, stylet (lower magnification) actually entered.

far as the potato is concerned, one lesson to be learnt is to start the potato crop afresh every year with seed potatoes obtained from a district free from disease.

There are in existence experimental breeding stations where new strains of potato are tested for their power to resist various diseases. Ormskirk, in Lancashire, is one of them. Those which stand the tests are certified as 'immune'. The grower is then able to choose the seed which suits him best, from the supplier's lists. You may see many injunctions to get Scottish seed potatoes. The Scottish Department of Agriculture has a scheme by which graded seed potatoes are certified as being and Government appeals are made to the public to be on the watch for the beetle or its eggs. I will pass on some of their recommendations to you. The beetle may be recognized by its yellowish body, traversed by black stripes which *run up and down*. Any yellowish-red grub feeding on potato leaves should be suspected. If such are found, they should be enclosed in a tin box with a piece of potato leaf, and sent to The Ministry of Agriculture, 28, Milton Road, Harpenden, Herts., accompanied by full particulars of the conditions in which they were found. The Ministry will send an illustrated leaflet, if requested.

CHAPTER XIV

LEGUMINOUS PLANTS

PLANTS of which the fruits are a legume, or pod, belong to the family of leguminous plants. They include our food plants of peas, broad beans, dwarf (French) beans and scarlet runners. Along with these belong the sweet peas which, I hope, shed fragrance in your garden, the wild vetches, and the clovers of farmland.

The exceptionally high food value of their seeds has already been pointed out. Bearing in mind this value, and reckoning up the ground at your disposal you have to decide which are the best to choose. The time for sowing will be governed by the ability of each of them to resist frost. Broad beans are so hardy that they can be put in in February. French beans are most tender; they must be looked after as soon as they show leaves, and given protection if frost is predicted. Scarlet runners also are only half-hardy. Peas are hardy.

You will probably discuss the merits of peas of dwarf habit and those of tall growth. Try out both. Choose two varieties, one of which is listed as growing one foot high, the other four or five feet. Give them exactly similar conditions to grow in, and continue to give them the same treatment. Then compare together the crop results, the time taken to reach maturity, and the amount of work they have given you.

The ground in which peas and beans are to be grown must be selected in the previous autumn, after consulting the plan showing the last cropping of the garden. They should not follow a leguminous crop; they might follow any of the cabbage tribe. They are, or ought to be, deep-rooted plants, so the ground must be loosened to a good depth and manure placed well down in it. They like plenty of lime. It is a good plan, though not usually practised, to open up the trenches in which the seeds are to be placed after the autumn digging is done, and to leave them exposed during the winter for purification by air and sun and frost. The trenches will vary from 18 inches in width and 6 inches in depth for scarlet runners to 12 inches and 3 inches for peas.

It is spring-time, when we put in our seeds so hopefully. The flat trenches are made, or are renovated by raking. Down the middle of each trench for peas make a drill about 4 inches deep. For runners, make two drills separated by a central ridge. The seeds are to go into these drills. Most of the seeds can be helped to germinate by being soaked in water for twenty-four hours before sowing. Scarlet runners form one of the exceptions.

Refresh your mind by reading what is given in Chapter XI about the broad bean and other seeds, and apply it to your rows of legumes. Ask yourself how deep the various seeds should be planted. The bulk of the broad beans may be covered with about three inches of soil; peas somewhat less. Place the bean seeds in the drills so that the micropyle faces downwards, seeing that the first root will grow out through it. Do not sow too thickly, though allowance has to be made for non-germinators.

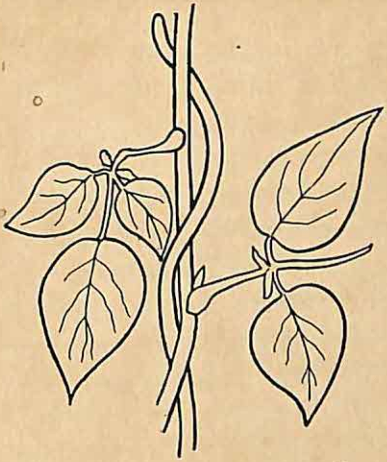


FIG. 23. SCARLET RUNNER BEAN SHOWING ONE STEM TWINING CLOCKWISE AROUND ANOTHER

You have opportunities of learning many almost personal things about the habits of plants if you take one or more of them under your own care at home, in a garden if you like or even in flower-pots. By watching the changes in them from day to day, giving them food and water at the right times, making little drawings of every new leaf or shoot or flower, and writing down what you think about it all, you may grow more and more attached to them. Keep your notebook with strict regularity, and be sure to enter up dates. Broad beans or runners would suit this purpose very well.

As your peas and beans on the plot grow up, compare their habits of growth. How fast the stems of scarlet runners shoot up, as if they actually were racing to get to the tops of the poles! They have no time to grow thick stems, but they must rise. So they lay hold of any support they can get by which to haul themselves up. When they get it, the stem winds itself round it, always in the same direction (Fig. 23). What direction?

Peas have another plan for making something else hold up their thin stems. Make an examination, and you will see that at the top of every group of leaflets several of them do not become leafy at all, but remain string-like. We speak of these as **tendrils.** At first, they are straight. Stroke a straight one gently with a rough twig. You might call it 'touchy', for it begins to curve and coil. The same happens when a young twig happens to touch a thin branch or other object; if this is thin enough they twine round it and cling there. If you want to see whole colonies of plants trying in one way or another to hoist themselves aloft on the shoulders of others, as it were, go and investigate a few hedgerows. You may find vetches which are near relatives of your peas, Robin-run-the-hedge which digs its sharp hooks into everything soft, convolvulus which winds like a scarlet runner, brambles holding on with sharp hooks, hops, and traveller's joy, or others. All are determined to get up to the light that their flowers and fruit may be displayed. Growing in the deep shadow of the hedge, their stems have a good chance of growing fast; you saw how light checked the growth of the stems in potato sets.

If your school possesses fair-sized cloches, you might try some experiments in hastening growth by means of them. Another idea to test is that of reducing scarlet runner plants to a dwarfed form.

When the plants have developed four or five leaves nip off the terminal bud. They will throw out side branches. As soon as the number of leaves is about doubled pinch out the shoot tips again. Continue to do this at such intervals that you train your plants into bushes not more than a foot and a half high. You have, of course, saved all the trouble and expense of putting up very tall poles. The size of the crop must be considered. Compare the yield with that from a row allowed to grow in the usual way.

From quite early in their life, broad beans must be regularly inspected to see if the notorious **black fly** has started to suck the juice from the soft tissues in the buds at the top. If there is any sign of it—and its black body is evidence enough—cut out the top bud altogether, and dust the plant with nicotine powder. That *may* check them. You may be surprised by the rapidity with which a whole plant may get covered with a sticky, black layer of these **aphides** (p. 113). They may have migrated from weeds like docks or nettles which are growing near by.

Peas may suffer from **thrips,** or from **green fly,** which may be checked with nicotine dust. Late sowings of peas are liable to be attacked by mildew; these may be dusted with sulphur. Thrips are small flies which suck the sap out of leaves. Green fly (otherwise, aphides) is a nearly universal pest, ready to feed on anything. There are many species of it. We have already become aware of some of its guilty actions (p. 113). The pea and bean weevil is another pest of these crops. (Fig. 24.)

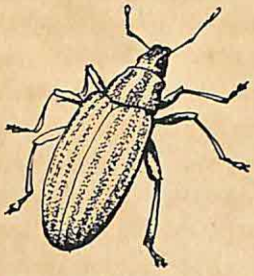


FIG. 24. PEA AND BEAN WEEVIL (About twice natural size.)

Now I will try to tell you what I consider to be one of the fascinating tales of science. Its little folk are good-natured 'brownies' helping the world of living things to keep alive. They are a family of the bacteria, living underground in homes which they construct for themselves. When your beans or your peas are gathered, dig up whole plants and look closely at their roots. If all has gone as it ought to have gone, there will be scattered all over them swellings, or warts, or nodules, of sizes up to that of a small pea (Fig. 25). These are the houses which our special bacteria have caused to grow up *around* themselves. The family has rather a terrifying name which I will not inflict on you. Some of the house-builders were living in that trench before the beans got there. They, you might imagine, watched the first roots grow out, and the fine root-hairs come into existence. They made no mistakes as soon as they perceived the signs which told them that it was time for them to move into a hair. How these signs were given is too complicated an affair for you to understand at present. They did get into the root-hairs, and then they started quite new work, which for some reason they could not undertake outside in the soil. It is truly one of the 'star' experiments of the scientific world: *they take free nitrogen from the air and make it unite with* *oxygen.* It sounds simple. It is the same old story which I told on p. 62; the difference in this version is that the bacteria now have a roof over their heads.

From the root-hairs they pass along into the other cells of the rootlets. There they get very busy. In some way they incite the tissue to increase greatly, so that the swellings grow larger and larger. The bean plant raises no objections. In fact, the two house-dwellers set up a sort of partnership. The plant treats the bacteria to what sugar they want from its sap; the bacteria make lavish return to the bean in the form of nitrogenous food. This the bean seizes upon, and hoards up in its seeds for the future use of the embryo which it is going to leave behind it. Is it any wonder then, that when we want nitrogenous food—that is, protein to replace our meat supply, we should have recourse to peas and

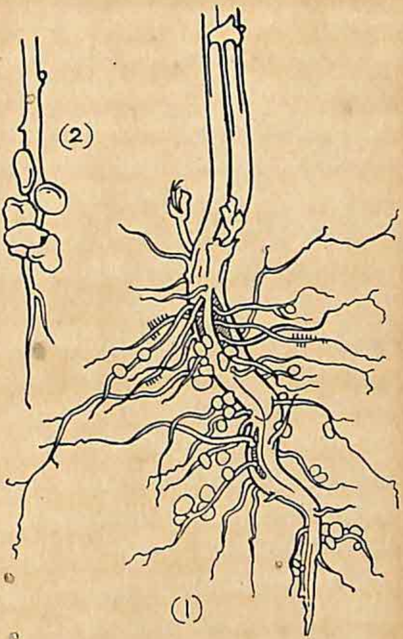


FIG. 25. ROOT SYSTEM OF A BROAD BEAN

Showing the nodules on the rootlets in the month of July. (Nodules enlarged in small figure.)

beans. You may refer to the analysis of these given on p. 101. What an amazing story! And true.

When the bean roots die, the nodules break up, and some of the bacteria return to the soil, to rest and be ready for next year. When you remove the decaying stalks, it is well to leave the roots where they are. Seedsmen sometimes inoculate seeds with the right bacteria lest there should be none in the soil. (Fig. 14).

There is yet more to be told. During the time in which bacteria and bean are working hand in hand, the former may be manufacturing far more nitrogen into plant food than the pair of them want to use up. The surplus is, in some cases, sent out into the neighbouring soil, perhaps quite abundantly. When a leguminous crop is taken away the soil is left richer than it was to start with; this is very different from the usual tale of robbery.

Try this experiment, and see what results you get from it. I referred to it on p. 110. Plant a row of potatoes between two rows of peas; give half of the row the usual farm manure; give nothing to the other half. I wonder if the bacteria will feed the latter. When I first saw a man planting potatoes and broad beans alternately in one row, I thought this idea was at the bottom of the practice. It is not so, however, for the broad bean refuses to hand over any of its surplus to outsiders. Apparently it rests with the plant to decide about the charitable distribution; the bacteria have no say in the matter.

The behaviour of the leguminous plants forms a guide in settling on the next year's crop for that plot.

The gardener as well as the farmer has to follow a rotation in his crops. One of the rules followed is to arrange for a crop which makes heavy demands on the soil to go on ground which has been left well provided for by the previous crop. Hence potatoes could very suitably follow peas or beans.

If you live in the country you may be able to see how the farmer applies this rule. His grain crop may succeed grass with clover. The clover-grass year is more than a resting year for the land, for clover and its partners the bacteria are busy all the time enriching it. The farmer does his share by sowing wild white clover and manuring with basic slag which gives the bacteria two substances which they crave for—phosphates and lime. Red clover has more luxuriant foliage than white, and suits some land better. The white clover spreads rapidly by sending out long creeping stems which give rise to new plants at the end of them. So we have bacteria, clover, grass and sheep; one dependent on the other. You should ask to be allowed to inspect a grass field with its clover intermixture. I have already told you of the use made of leguminous crops for bringing barren land under cultivation.

Try sowing your peas at such an early date that they will have to face midwinter conditions. Here is the result of a trial of my own. In December I prepared a trench about 9 inches deep, put at the bottom of it a layer of decaying leaves (the soil being very porous), drew a layer of soil over the leaves, planted the seeds in the usual manner with the usual compost; above the top layer of soil was placed a loose blanket of leaves about three inches thick. The sowing was made on December 9. On January 4, the green shoots were showing above the leaves, and apparently every pea had germinated. Later in the month the trench lay under a foot of snow for a week. The sides of the trench afforded some protection from cold winds. Foliage was profuse; flowering and setting of seeds was satisfactory. The crop was ready for gathering (after a very unfavourable growing season) on June 12. Successive sowings of peas were made as usual during the season, but weather was so bad that the first crop turned out to be the only one of value.

Having done so well with this venture, I went on to repeat it in the next year, following precisely the same procedure. The result was complete failure; three seeds germinated. What was the explanation? That I do not know; perhaps poor seed, more probably because the ground temperature was not right at the time of sowing. I must try again. And that is one of the lessons to be learnt in gardening—that we must search for the reasons for our failures.

CHAPTER XV

THE CABBAGE FAMILY AND OTHERS

CABBAGES

The cabbage family includes cabbage, kale, Brussels sprouts, cauliflower and broccoli. They are also known as **Brassicas.**

Slice in both directions two 'hearted' cabbages. It is quite evident that a cabbage is nothing else than an immense bud of which only the outer leaves have unfolded. The inner leaves are yellow (**etiolated,** the botanist says); we ascribe this to the absence of light and therefore the absence of chlorophyll. In the Brussels sprout, the numerous 'sprouts' are small buds which have not opened out.

The excellence of most of the Brassicas depends on the luxuriance of the foliage; manuring is directed towards the encouragement of this quality. The big body demands plenty of nitrogen, and fertilizers are chosen accordingly—sodium nitrate, sulphate of ammonia, and, for wintering plants, 'Gromore'. Any organic manure used should be dug in months before; it should not come in contact with roots as an attraction to pests. The mineral fertilizers are worked into the surface soil in small quantities at prescribed times. In the case of broccoli and cauliflowers, the head of flowers is the edible part; they require more generous treatment with manure. The ground should be made very firm for these heavy, leafy plants; sprouts may even need to be staked, to withstand wind.

Try raising your young cabbage plants from seed, following the directions given on p. 95. They will be ready to plant out when they are about nine inches high, (or less, if weather suitable). In spacing them out in the rows, bear in mind the size which you wish them to attain, and allow plenty of room. Sprouts may be as much as three feet apart. Let there be no delay in planting after lifting, lest root-hairs should suffer.

You may nip off any long central root tip; this will probably induce the formation of a bunch of fibrous roots and a more sturdy growth. Here are some details of the procedure which are applicable to the planting out of most seedlings; the object of them is to leave the soil in very close contact with the smallest rootlets. Make a cup-shaped hole and loosen the soil at the bottom of it; pour in water or soot-water and let it settle. Holding the plant in the left hand, put it in place, spreading out the roots gently (that is, if they have lost their clinging soil, as when bought from a shop); cover the roots with fine soil, patting it close in with the hand or a convenient tool. The final filling in of soil should reach just to the level of the lowest leaf. It is a good plan to make the hole large enough to leave the cabbage seated in a saucer-like depression; this keeps water where it is wanted when you are watering.

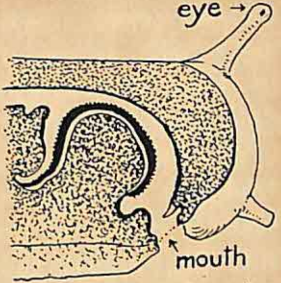


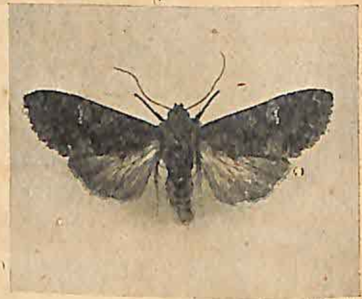
FIG. 26. Vertical section through a snail's head, showing the mouth parts and toothed tongue.

When the plants are fairly well grown they have to be earthed up and made firm round the stocks. Occasionally, a little 'Gromore' may be worked into the soil close to them.

The lives of the cabbage tribe are not made easy for them. In wet weather and in dry they are preyed upon by crowds of enemies—slugs, snails, butterflies, moths, root-flies, fungus, virus.

In some wet seasons you may have many a weary hunt for a plague of small shell-snails. They travel into the very heart of cabbages and hide there; your only course is to pick them out and crush them.

Sometimes the gardener thinks his heart will be broken by slugs and snails, many of them hiding by day, coming forth in the darkness to devour every choice green morsel. They spend the winter in the soil and the eggs are laid there. I daresay you are familiar with some of their features—that thick 'foot' which it pushes out in order to creep along leaving the trail of mucus with which it has smoothed its path; the horns, the long ones bearing eyes, the others with which it smells out your strawberries. A leaf on which it has done some work shows how it has filed or scraped the substance away with the toothed ribbon which works in its mouth.



Harold Bastin

FIG. 27. CABBAGE MOTH
(About natural size.)

You really need to know the life-histories of the white butterfly and the cabbage moth (Fig. 27) if you are to wage war successfully against them. You may find out in what respects they differ from that of the bee. You might keep some of them in glass-topped boxes and watch what happens. On a sunny day flocks of the insects may flutter about the garden. You pay a visit to a cabbage leaf: examine that leaf, and almost certainly you will find a cluster of whitish eggs stuck to its under surface. You save much future trouble if you squash these at once. Plenty of them will escape you, and the next you see of them is as caterpillars—those of the butterfly, green to yellowish; of the moth, greenish or flesh-coloured. These are the **larvae**, whose sole occupation seems to be feeding themselves. They have biting mouths; from the tremendous amount which they eat they store fat in their bodies. Picking them off the leaves by hand is a dreary but necessary job.

When the caterpillar has had enough to eat, it retires into seclusion in the ground. The scientist says that it '**pupates**'. It does not actually go to rest, for the most elaborate changes are being made in its body during this motionless stage. At the end of it there emerges from the web in which the larva had wrapped itself up the beautiful insect which wings its way into the sunshine.

The new insect destroyer known as **D.D.T.**, if sprayed or dusted on the leaves, destroys caterpillars completely; but it does not prevent egg-laying. More information about D.D.T. will be found on p. 158.

The roots of young Brassicas are often attacked by the cabbage root-fly. Its eggs are laid in the earth close to the plant and produce legless maggots which attack first the roots and then the stem. Drooping leaves give the first sign of this. The first flies appear about the end of April, and there may be two or three broods in one year. The base of the plant should be dusted with calomel or naphthalene dust, after putting out, and again a fortnight later. Tarred felt disks placed round the stems may keep the flies at a safe distance. Dig up and burn infested plants, together with the soil around them.

Some soils are almost hopelessly infected with the fungus which causes finger-and-toe, or club-root, in cabbage and turnips. It is a minute, low-grade fungus, which penetrates the plant tissues and gives rise to swellings. The only hope of checking it seems to be heavy liming of the ground. The plant stocks should be burnt at the end of the season. Brassicas must never be put on the same ground in successive years.

INSTITUTE OF EDUCATION FOR WOMEN
Dept. of Extension
SERVICE.
CALCUTTA

CARROTS

Examine a whole plant and see if you can decide what part of the plant it is which we eat. There are no 'eyes' here as in the potato tuber; but there are numerous fine rootlets which look as if they might take food from the soil. The thick organ is an enlarged root. A very short region at the top bears the leaves and is all that stands for a stem. As a rule, nothing else appears on the plant during the first year of its life; in the second year, the flowers develop. A plant which takes two years to reach flowering stage is known as a *biennial*. Those which manage it in one year are *annuals*. Do you see now the reason for the thick root? The first year's leaves send down supplies of food to be stored there in readiness for a quick start with flowering in the second year. This means a great deal to us, for we take over these very stocks for *our* food. Plant breeders encourage the growth of large storage roots in carrots, parsnips etc.

In preparing the ground for carrots never apply farmyard manure, as it attracts flies. Rake the surface to a fine tilth. Seedlings should be thinned early, or the roots will become misshapen. When they are about three inches high they may be stimulated with a little sulphate of ammonia. Soot and wood-ashes give beneficial effects.

A whole crop of carrots may be ruined by the carrot fly without your seeing a single one of the little pests (Fig. 28). So serious is such a loss that a great deal of research has been devoted to the question.

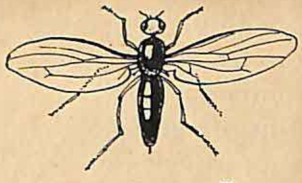


FIG. 28. CARROT FLY
(About 1⅓ times natural size.)

Some special work was done on it recently at the Royal Horticultural Society's Gardens at Wisley, and I think I cannot do better than give you some of the results which were published. The full account would have shown you how patiently and thoroughly such work is carried out.

The fly itself is a shiny black insect, one-third of an inch in length, having one pair of wings. Its very small white eggs are laid in crevices in the soil close to the roots. They hatch out in about a week into colourless maggots which feed on the roots. When these larvae are full-grown they pass out into the soil for the usual rest period, from which they emerge as flies. They manage to send out two generations in one year, one in April-June, the second in late July-September. The first brood appears in vast numbers near the site of the previous year's carrot crop; their larvae had spent the winter there. They dislike wind, and shelter, between their depredations, in any rough herbage which is at hand.

The following are the preventive measures which the Wisley workers recommend. Never sow on last year's site; use no farmyard manure. Use every means to make it hard for the fly to probe into the ground to lay eggs, by packing it close, thinning and weeding with care, thinning early, watering heavily and pressing soil close up. Bruised leaves must not be left about, as the odour attracts the flies. Sow in an open situation, distant from rough foliage, especially nettles and potatoes, which seem to be favourite harbours for the flies. Sow the main crops in late May-June, or in July, and lift in mid-October. You may supplement your efforts with applications of creosote, naphthalene, or other stuff having a disagreeable smell.

You might experiment with soot on part of your carrot crop, comparing results with the part treated normally. One authority believes so strongly in the value of soot for carrots that he applies dressings of it at three separate stages. The first is worked in when he is digging the ground, the second when he is giving the final rake-over to the seed-bed, and the third after the final thinning of the seedlings. See what you can produce by following this procedure.

Still another recommendation might be tested by you. It is to place layers of short grass cuttings close alongside the rows of carrots at those critical times when the flies are probably most busy. It is said that the flies dislike the smell of decaying grass. The layers would have to be renewed.

Finally, there is D.D.T., applied at the same dates as the grass. I tried it last year, and not a single carrot was affected. But when I mentioned my good crop to a friend he said—'Yes, it has been a good year for carrots'. And that answer points to the main precaution to be taken in testing the effect of any treatment you apply. You must make sure that, as the scientist says, 'Only one factor is changed'. This means that you vary the treatment in only one particular. In the case of my carrots, there might, for some reason or other, have been no carrot flies at work in my garden that year. If I had planned a proper experiment I would have treated one set of carrots with D.D.T. and left a second set without it. Such an untreated set is called a *control* in scientific work.

The carrot and how to combat its enemies would make quite an interesting subject for research by a school class.

TURNIPS

Examination shows that turnips, like carrots, are swollen roots. They, too, are biennials, though sometimes they flower in their first year.

The introduction of the turnip into field cultivation at the end of the eighteenth century caused somewhat of a revolution in food customs. The turnip crop was given a place in the three-year system of farm rotation in place of the year of 'fallow'. This was equivalent to an increase in the extent of arable land. It meant more, for cattle could now be fed throughout the year instead of being killed and salted down in late autumn. Hence more fresh meat. The turnip crop made only slight demands on the soil, and left it in a condition to bear a heavier crop.

In the garden, prepare the ground by liming it well in the preceeding autumn. No manure is given in spring, except perhaps a little superphosphate.

Sow *very* sparsely, and thin out as soon as the plants can be handled. Thin several times. Growth should be rapid; potash manures may be given as stimulants.

The turnip-fly attacks seed-leaves. It may be warded off by watering the very young seedlings several times a day, and strewing over them soot, wood-ash or even dust. A little beetle trap has been invented to catch another pest, the flea-beetle; it is pushed along the rows at the early seedling stage.

Club-root has already been mentioned (p. 131), as well as the only likely preventive—lime. It reaches its worst on ill-drained ground.

PARSNIPS

Parsnips are very deep-rooted vegetables, and this must be encouraged. The ground should be dug as deeply as is convenient. It must be remembered that such tap-rooted vegetables should not be transplanted.

To secure long, undivided roots special preparation has to be made for each plant. The method also secures quick growth and avoids stringiness. Make a line of holes one foot apart, using a crowbar to get down about two feet. Make them about six inches wide at the top. Fill this hole nearly to the top with a prepared mixture, sieved and well mixed; it may consist of loam, wood-ashes, sand, decayed refuse and perhaps a little superphosphate. Into each hole place four or five seeds and cover them with sifted soil. Thin out the seedlings, by degrees, until there is only one left in each hole.

By spacing out your seeds from the beginning in this way you avoid wasting seed, and you save labour when it comes to thinning out. The concentration of the feeding material just where the long tapering root can get it by growing straight downwards produces well-shaped vegetables of large size. Most of my last crop weighed 2½ pounds each, some being ¼ pound more than that. They were also sweet and delicate; these are qualities which must not be sacrificed for the sake of size.

BEET

This is another root-storage organ. The food stored is sugar. If you cut it across you will see how it is layered as new growth was added.

The ground for this crop should be prepared long beforehand. Stable manure is not added at sowing time, as it would cause the roots to fork. Some superphosphate may be forked into the soil before sowing. Wood-ash applied occasionally encourages the formation of sugar.

The plants may be cultivated in the same way as parsnips, the hole being filled with sifted compost. This suits the long-rooted varieties.

Recent experiments at Rothamsted Experimental Station have shown how heavily the application of common salt increases the yield of sugar in the field crops of beet. A few shillings' worth of salt was reckoned to be good for five hundredweights of sugar. Try a little with your garden beet.

Care must be exercised in lifting beet and in removing the leaves to prevent 'bleeding'. Moreover the skin must not be broken in cooking.

ONIONS AND LEEKS

An onion from the store and an onion as it grows must be compared if you are to obtain a correct understanding of what an onion bulb really is. When you cut across a dry bulb you find concentric layers of thick fleshy scales enclosed in a few dried brown scales; all of them finish up at the top in ragged edges (Fig. 29). These parts are attached to a harder stumpy base. (A bluebell or tulip bulb might be better for study.)

A partially grown bulb taken from the ground explains the structures. The scales are the bases of

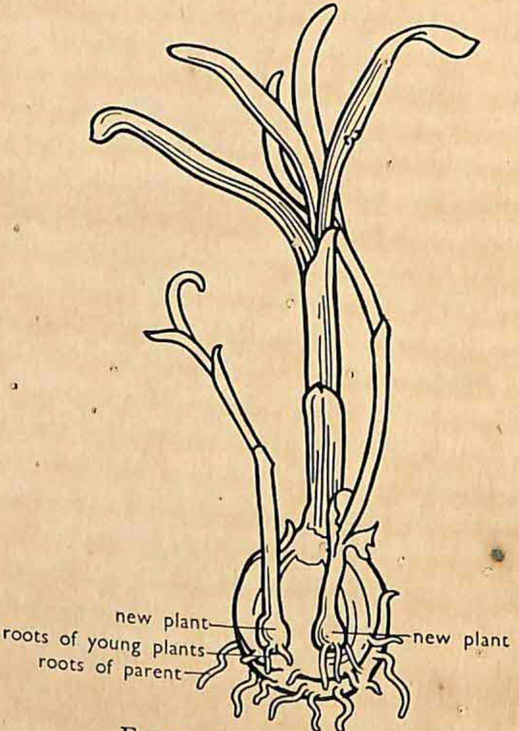


FIG. 29. BLUEBELL PLANT

Diagram of a plant in May, showing new bulbs arising from the axils of the storage leaf-bases which have been removed.

leaves which are continued upwards in green, tubular form.

If you strip off the papery scales from an onion bulb and leave it for a day or two, you will find that the outer of the juicy scales have become flabby. Evidently the thin scales prevent the loss of water.

Watch the continuous swelling of the bulb in the young growing onion; the green leaves are sending down storage material. It is necessary, as in other cases which we have considered of biennial plants. The leaves die down at the end of the first year. If left for a second year, there would develop a tall, thick stalk bearing a globular head of flowers. Cultivate one to show this. Watch an onion which starts to sprout in the store-cupboard, and note how the sappy leaf-base scales empty as the new leaves unfold. You may make a comparison with the development of peas and beans, which store for the benefit of their seedlings and complete their own life-story in one year.

The leek is essentially akin to the onion; but the lower parts of the leaves are lengthier and not so markedly thickened. Shallots are onions. They give rise to clusters of buds which develop into bulbs encircling the parent. To get the best results the earth should be scraped away from around them as they begin to swell. Onions also, in their latest stages, should be allowed free space. Leeks are well buried, to blanch them by excluding light.

The onion bed must be set going in the previous autumn by working in plenty of rich manure. It should be trenched during the winter, and finally

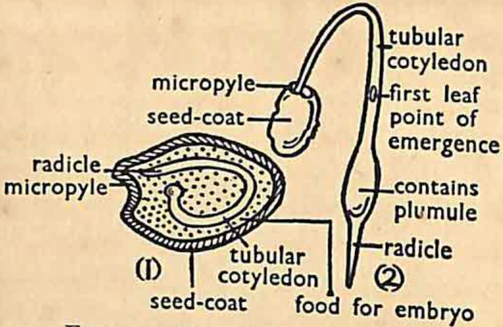


FIG. 30. GERMINATION OF ONION
1, Onion seed cut open; 2, onion seedling.

raked to a fine tilth. On a suitable day it is trodden hard. Leeks may have manure applied in spring; they are put into a trench or hole; the soil is not trodden, but is drawn up round the plants several times. The soil for onions and leeks should be well limed.

If you germinate a few onion seeds in pots you will find interest in the way in which the first fragile-looking leaf makes its appearance. It is a tubular seed-leaf, and its top remains fixed within the seed in the soil at first, so that it forms a curve. (Fig. 30). Here you have only *one* cotyledon, whilst in all the seedlings which you have examined up till now there have been two. This character is used for dividing up all flowering plants (except the coniferous trees) into two great groups—**Monocotyledons** and **Dicotyledons.**

Onion seedlings are delicate. They may damp off, owing to fungus, if they are kept too moist.

The onion-fly is a danger to the bulbs. It lays its eggs round young onions, and the maggots eat into the bulbs, coming out as usual to pupate in the soil. The last brood stay there all winter. Soot is supposed to keep off the flies.

CHAPTER XVI

THE GARDENER AND THE WEATHER

THE WEATHER brings sorrow to the gardener in some seasons. You may have toiled for your garden's good for months, and up to a point all seems to be going well. Then there comes a time when you watch the sky for weary weeks, looking for the cloud which will bring water to thirsty young things. Or you may see your strawberries rotting, your plums splitting, your green stuff and your weeds running riot; then your spirits go down with every day of rain. Spring may bring summer-like days out of season, and blossoms and young leaves are tempted forth. Then comes a frost or bitter winds, and the fruit crop is ruined.

No wonder the gardener watches for every sign which may give warning of coming weather changes, that he may take what precautions are possible. Plants may be covered up to save them from frost; seed-sowing may be delayed.

He hopes for good hard frosts in winter. He depends on them for killing at least some of the pests which winter in the soil. Frost helps him in breaking up the soil into friable condition.

For everything which you do in your garden you must choose the most suitable weather. This does not always fit in with school time-tables; but you must know how to apply the rules for use in gardens of your own. Experienced gardeners say that there is a correct day for every garden operation in the course of every year. For digging, the soil must not be so clammy that it sticks to the boots; for seed-sowing, it must be nicely powdery; for harvesting, when fruits and vegetables are dry. If you can, choose showery weather for transplanting; a dry sunny day is the best for your hoeing, as the rootlets of the little weeds which you uproot will shrivel up quickly.

You will consider, when you are choosing what you will plant and when you will plant, the climate of your locality. Is it exposed to strong cold winds? Is it Kent or Yorkshire or Devon? The gardening catalogues label some plants as half hardy, and these you must protect in some measure, and delay in planting out.

It is a part of your training to keep your eyes open for the effects which extremes of weather have upon certain plants; there is a great deal to be learnt on this subject which is of importance to our food supplies. See what you can find out about what happens to leaves, buds, flowers and fruits—all in their young condition—when they are subjected some night in late spring to a sudden frost. Note how delicate they all are, how thin are their skins, and how full of moisture they are. Sometimes soft little leaves are blackened and die; sometimes they are blistered and wear into holes. The cabbage plants in your seed-bed may become yellowish if there is a long spell of low temperature, which prevents the formation of chlorophyll. Plants like potatoes which have been brought to our gardens from hot countries may have their leaves quite destroyed by a touch of frost; they may recover and produce a new set if they are at a suitable stage of growth.

Fruit-growers are always anxious about their apple blossom even before the buds have opened, for the style of the flower may be destroyed then, and of course no fruit will result. The strawberry bed which one day had been starry with beautiful flowers may after a night's frost look not much the worse; but in a day or two the centre of the flower becomes a black spot, filled with shrivelled dark anthers; all hope of fruit from these poor flowers with their 'black eye' has gone.

The cold east winds of spring do damage which resembles that of frost. You should examine different kinds of buds which were formed in the previous year and which live in a resting condition during the winter. You will find how wonderfully the tender inner structures are so well wrapped up in cases of scales that they have nothing to fear from weather. They are guarded against cold and damp, but also, which is even more needful, they are protected from the loss of their sap. When spring comes and the sap is rising plentifully the swelling little leaves burst through their coverings. That is the time of danger, for they have not yet acquired the waterproof skin which they will have when full-grown. If at this time they are exposed to a 'drying' wind, they are robbed of their moisture, and shrivel up; sometimes they look as if they had been scorched.

I expect that you, as a class, will make a regular study of the weather reports as they appear in the newspapers and are broadcast on the radio. Also that you will possess a set of instruments for ascertaining the prevailing weather, and will prepare records from your readings of them. Comparisons will be made with those compiled by previous classes and with the garden results associated with well-marked weather conditions.

The instruments required are a barometer, a rain-gauge and a maximum-and-minimum thermometer. You will want to know the way in which each of them acts. I will not describe them in detail as I expect you to have a lesson based on the instruments which are in use in your school, and instruments vary to some extent. I will deal only with the scientific principles on which they are constructed in order that you may have them by you for reference.

The **barometer** does not prophesy about weather directly. What it does is measure the weight of the atmosphere which extends overhead at that place. The story of its origin goes back to 1643, when an Italian called Torricelli made a very simple experiment which revealed a great truth. He filled a tube 36 inches long, closed at one end, with mercury. He placed ready a bowl of mercury. Holding his thumb over the open end of the tube, he turned it upside down, inserted the thumb end within the mercury in the bowl, and then withdrew his thumb. Would you not expect the mercury in the tube to empty itself into the bowl? Well, it did not. It certainly fell a little lower in the tube—until it stood at a height of 30 inches above the mercury in the bowl, in fact—and there it stayed. Above it was what looked like empty space, and really it was so; it was a **vacuum,** containing not even air. This was a most important fact.

Torricelli knew of another scientific truth discovered before that by Pascal, namely, that if any pressure is applied to a fluid it travels in all directions through the liquid. Something was pressing downwards on the surface of the mercury in the bowl; the force of it moved in all directions through the mercury, including an upward direction against the mercury in the tube. It was able to counterbalance the force of gravity which was urging that mercury downwards. The pressure which was doing this was that exerted by the column of air, some 200 feet high, which is the atmosphere lying above us. This is what the experiment was weighing, so to speak.

When such an experiment is performed at the top of a mountain, the length of the mercury column is less than 30 inches, which is what we would expect, seeing that there is less air overhead.

It was no other than this simple tube which was fixed up with a scale, and turned into a barometer. It was used in making a long series of observations connected with weather forecasts. One fact which came to light was that when the mercury rose in the tube, fine weather was generally on the way. This was explained partly by the fact that dry air exerts more pressure than moisture-laden air. There are other considerations which I cannot enter upon here.

We pass on to consider the **thermometer,** which indicates the temperature of the air. Examine the one which hangs in school. You again see a tube containing mercury. This tube is closed at both ends, and is of very fine bore. In the making of it there is experienced difficulty in getting air out of it and mercury into it. The part of the tube above the mercury contains no air. After it has been filled, freezing point and boiling point have been marked on the attached scale. To obtain the first, the bulb is immersed in pure ice, and a mark is placed at the level at which the mercury stands. The same is done for boiling point by placing the instrument in steam from boiling water. In what is called the **Fahrenheit** scale, freezing point is marked 32°, boiling point, 212°, and the space between them is divided into 180 equal parts. In the simpler **Centigrade** scale, freezing point is 0°, boiling point 100°, and the space is divided into 100 parts.

This is the thermometer with which we are familiar; other substances may be used. The first thermometer was made by Galileo, who lived in Italy between 1564 and 1642. He made some great discoveries. His thermometer contained water. The principle is the same in all of them. Their action is dependent on the substance employed expanding at a steady rate when its temperature is raised. Perhaps you can have some simple experiments made in school to show this.

For garden purposes certain variations on the simple instrument are most useful. One type registers the highest temperature which has been reached during any period in which it has been left unwatched. Another indicates the lowest, for example, during the night. They are known as maximum and minimum thermometers. In one form, called **Six's**, the two are combined in one instrument; this is in general use with gardeners.

In the simple maximum, a small marker (a float) of glass or steel is enclosed in the tube. As the mercury moves upwards this is pushed ahead of it; if the mercury retreats the float is left behind, and the end of it next to the mercury tells the highest temperature reached. For this, and also in the minimum thermometer, the position of the tube is horizontal. In the minimum thermometer alcohol is used instead of mercury. A short glass rod within the liquid is carried back with it when it contracts. If the temperature rises again the glass stays where it is, the liquid moving past it.

If you have a Six's thermometer, you see a double tube; mercury and alcohol are arranged in it in a way which you will understand best by having the instrument before your eyes. The floats are both of steel, and a magnet is used for bringing them back to the 'set' position.

Rain-gauges are simple affairs. They consist essentially of a collecting can so made that water does not evaporate freely from it. For use along with it there are supplied a graduated glass bottle and a graduated glass measure. The position of the gauge in the garden has to be chosen with some care. There are more elaborate forms of the instrument than I have described.

CHAPTER XVII

ODDS AND ENDS

MULCHING

I know one gardener, a very highly experienced demonstrator to gardening students, who puts mulching in the forefront of his recommendations. In my own garden, the soil of which is very light and sandy and dries out quickly, it is continually resorted to. What is mulching? It may be said in a general way that the practice consists of spreading on the surface of the ground, all round the plants as far as their roots may be expected to spread, a layer of manure or of vegetable cuttings which are left there to decay. Manure, when it can be got, is strong food, and is applied for special feeding purposes in many cases.

The mulching which I have in mind at the moment is the spreading of a carpet of grass cuttings or autumn leaves where they will benefit such plants as fruit trees, raspberry canes, gooseberries, tomato plants. In some gardens it pays to renew the mulches several times a year, forming practically a permanent layer. You may apply the scientific knowledge you have acquired to reasoning out the advantages gained.

The autumn applications prevent loss of heat during the winter months, for we know that any loose material with plenty of air in its meshes is a bad conductor of heat. The summer mulches protect the soil from excessive heat, and prevent loss of moisture; this is of special importance in soil which does not retain water well.

Then the rotting vegetable stuff is all the while adding a little manure to the soil below it. To prevent any leaves which you use from drifting about toss a spadeful of soil over them; this will not only keep them in place but will also regulate the rate of decay (as in a compost heap).

The raspberry bushes in my garden have to root in the poorest of soils; but they bear wonderful crops both as regards quantity and quality, year after year. They get no regular manure (at first, because none was to be had); they are kept under a perpetual mulch of grass cuttings. My outdoor tomato plants sit in a shallow basin of soil, their roots covered over most of the time with grass cuttings. This means less watering, less risk of drying out, a better regulated water supply. When the grass is moved aside, the difference between the damp soil covering the roots and that exposed is very evident.

Another advantage gained is that very few weeds flourish under the grass mulch.

Mulching may serve yet another purpose. The carrot fly is said to dislike the smell of decaying cut grass, so you may pack short grass cuttings close up against your young carrots, and try the effect of it (p. 134). Making of it an experiment, you will grass part of your crop and leave the rest of your crop ungrassed for comparison. As the grass decays quickly, there will have to be several applications.

WATERING

Whenever you feel that you must water your plants, do it thoroughly well. Try to imitate the rain which soaks far down and starts a store of water. Sprinklings are licked up by heat almost immediately. Water must get down to roots. An uninterrupted supply of water must be furnished to seedlings, whose delicate roots lie in the driest layers of the soil. Do not give your plants water straight from the cold tap; draw it and leave it outside to warm up. Remember that roots cannot absorb it below a certain temperature.

WEEDING

Weeding, I have no doubt you will discover, is a job which has no end, but which ought to have a very early beginning. Legions of seeds are hidden in every spot, ready to thrust themselves into existence. They are fast growers, and often a plant which we cherish is unable to compete with them. Keep the hoe going regularly over the whole free surface to prevent them from even getting a start. Those which creep into the shelter of your seedlings must be nipped out with finger and thumb. Not one must be allowed to remain in hiding, for they are robbers, greedy for food and water, absorbing more than vegetables do, especially phosphates.

The whole gardening class might make an interesting botanical study of the methods by which weeds spread from place to place, extending their research into farmland, if possible. Weeds are an annoyance in the garden; but they form a serious problem for the farmer. The doings of the weed both above and below ground must be looked into. The dispersal of the seeds of plants is carried out in very many ways which cannot be given in detail here.

The dandelion gives us one example of a clever device for establishing a family at a distance from itself, as you may find out when you see its tiny fruits hanging from their parachutes as they sail along on the breeze. You realize that dandelions should not be allowed to reach the fruiting stage. Look at that insignificant chickweed. Its seeds are scattered at no great distance from itself, but several generations of them can live out their brief lives in a single summer, and they can soon cover yards of ground with their trailing mats. Birds aid hedgerow plants by carrying off seeds in the berries which they eat. You yourself may help to distribute Robin-run-the-hedge (goosegrass or cleavers) if any of its spiky little burrs (which are the fruit) stick to your clothes. The contrivances for scattering the seeds of plants seem endless; find out as many as you can.

You may be familiar with the way in which the strawberry plant gives rise to a family by sending out long thin **runners** which root themselves at the tips and there grow up as new plants, thus multiplying independently of seeds. Well, have you any of the pest called coltsfoot in or near your garden? If you dig into its underground affairs you will find that it does exactly the same as the strawberry, only it keeps its runners (known as **rhizomes**) out of sight. To get rid of it you must remove every scrap of these shoots, for if one piece bearing a node (joint) is left it is capable of sending up a bud to expand into a new plant. Some grasses travel underground; couch-grass is the worst of them, and is very difficult to get rid of. If you start to dig out a dandelion, be sure that you bring out the whole of its obstinate root, for it is able to produce buds from its roots. When you know how easily a plant can send its children abroad you will naturally be on the look-out for weeds in any rough spots adjoining the garden, such as a hedge. A piece of uncultivated ground close to my garden sent me over many a crop of grass and other weeds.

An interesting extension of the class-study of the dispersal of plants might be made if there were easy of access a piece of ground which had been cleared of vegetation and left to Nature. Such ground becomes colonized by degrees with wild plants (many of them weeds of the garden). A series of observations, continued for several months, would disclose which were the most successful travellers.

THINNING

It is not always remembered in practice that the thinning out of young plants must be done in most careful obedience to scientific principles. Think of the plant's requirements. There must be sufficient soil in the near neighbourhood of its roots to enable them to move out and gather in food and drink;

otherwise there is no possibility of satisfactory growth above ground. The young stems and leaves must not be crowded together so closely that every plantlet cannot get all the light it requires. You have learnt on other pages how stems growing in weak light are likely to become long and thin and feeble. Seedlings show this tendency at a very early stage. If the young plant is to have a fair chance of growing up sturdy and strong it must have free space below ground and above ground.

It follows that you must begin the thinning process as early in the seedling's life as you can handle it; in fact, it is possible to pick out very tender little ones with a pair of tweezers. More than one thinning will usually be needed; you must be guided by the particular requirements of each plant. Keep in mind the size that will probably be reached by the adult plant when you are deciding about your final thinning. In the case of carrots, onions and turnips, thinnings which have reached a usable size may be utilized in the kitchen for stews etc. Handle the delicate plants with all care to avoid bruising those which are left. Disturb the ground as little as possible, and be sure to make very firm the soil lying round the roots; loose soil makes things easier for the pests which are anxious to lay their eggs conveniently near the roots on which the maggots may feed (p. 131). Evening is the best time for thinning, to avoid admitting hot dry air to the roots which are left in place. If the ground is not already moist, it should be watered and pressed close together after thinning.

LIQUID MANURES

It has already been made clear that the nourishment which a plant takes into itself must be in a state of solution. You will have experimented already with substances (such as nitrates) from your stock of bottles, to find out how quickly each of them will dissolve in water. If you look at the quantities used in the culture experiment on p. 80 you will realize how extremely weak are the solutions which are used. It has been proved that strong solutions may be actually harmful to the plant.

Useful solutions of plant food can be made for garden use without aiming at exact quantities. The liquid manures in general use are those made from soot or from animal manure. The substance is put into a strong bag and this bag is suspended in a tub or barrel of water and left there for a few days. Soot may be mixed into a paste first. Chemical matter will pass out into the water. Before using the water as a manure it must be diluted until the colour is that of very pale tea. Applied to the soil around plants it brings food substances quickly into close contact with the whole system of roots, acting thus as a quick stimulant to growth. Soot contains from 5 to 10 per cent of ammonium salts, which means, of course, that soot furnishes plants with nitrogen, which is particularly acceptable to seedlings for their quick establishment. Liquid manure may be of special service to plants which are backward because they have exhausted the food supplies in the soil round their roots, for example, in pot plants. It is helpful to young plants with weak root systems. Parsley, onions and carrots, in the young stage, are improved by dressings of soot.

USE OF SODIUM CHLORIDE

You have been hearing a good deal about supplying plants with substances containing potash; this chemical is potassium chloride. The chemical sodium chloride resembles potassium chloride in some of its qualities, and it might be supposed that it too would be of service to plants. Sodium chloride is very well known to you all for it is merely the common salt which you eat with your food. Gardeners actually used it as a fertilizer before the value of potash was well known. You might experiment a little with it in your garden.

It is well known that it improves the growth of asparagus. Try some on leeks, onions, cabbages and other Brassicas. Use about two ounces to a square yard, and work it into the top four inches of the soil. Further dressings may be applied whilst the crops are growing, using about half the above quantity. I daresay you know how salt gathers in moisture from the air in the house; when in the soil it helps to retain moisture there, which is of great value in sandy soil.

A gardener told me that he had cleared out club-root from a garden plot by treating it with large quantities of salt and lime mixed in equal proportions. Can you verify or disprove that?

FEEDING PLANTS

In addition to the general directions for feeding plants which bulk so largely in this book a few reminders about general principles may be mentioned here. In the first place give the food a little at a time and give it fairly often as the plant progresses. If the ground is dry, water the feeding stuff in. Give the precise food the plant requires (so far as you can calculate) at the moment when it is asking for it. Remembering that nitrogen is neces-

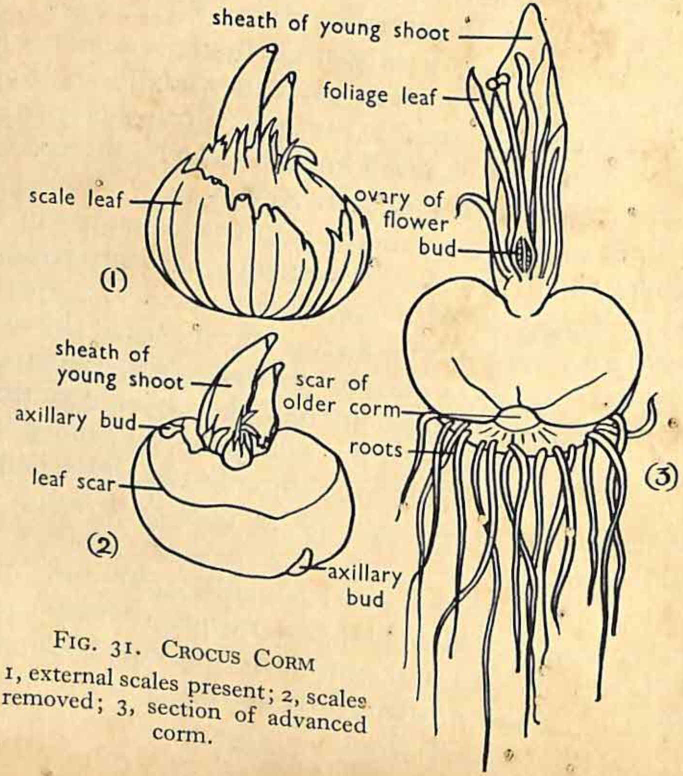


FIG. 31. CROCUS CORM
1, external scales present; 2, scales removed; 3, section of advanced corm.

sary for the foliage which builds up the plant body, give it nitrogenous manures in the early stages as a rule; not too much to tomatoes or you will have too much foliage and too little fruit. Following this rule, you will treat your spring cabbages, which you want for their leaves, to a little nitrate about February or March, when growing processes are becoming more active. Remember that potash salts encourage the formation of storage sugar and starch, so give them to your onions, carrots, beet, potatoes, as well as to tomatoes when they are ripening. Phosphates will help in early growth of roots, and they will also hasten the ripening of fruit.

FOOD STORAGE IN PLANTS

Towards the end of a year of gardening you might review all together the ways in which plants lay up stores of food; the subject is part of the question of why we make gardens at all—to get food for ourselves. There are two groups of plants which build up stocks of food—those which devote a year's work to making ready for flowering and seeding in the following year, and those which provide the little embryo in the seed with a large quantity of food placed close to it in order to give it a good start in life when it germinates until its new leaves are well advanced.

The tubers of the potato are mainly masses of starch; the onion bulb consists of fleshy leaves containing much sugar; the corm (the short, hard, underground stem of the crocus) is filled with starch (Fig. 31); beet is an example of an enlarged root rich in sugar, whilst the carrot contains grape sugar.

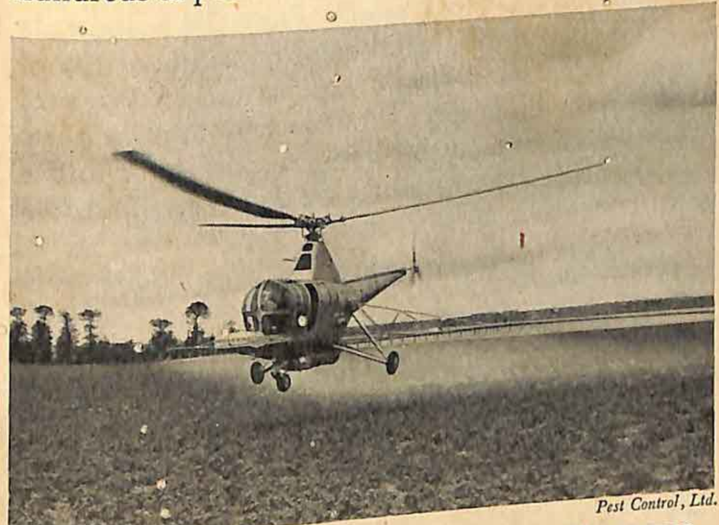
We use peas and beans to supplement the meat ration, depending on their containing much protein (p. 101). The plants that bear them have specialized roots which furnish much nitrogen (p. 122). What they have produced for their offspring, we take for our eating. We do the same kind of thing when we eat an egg, the varied nourishment which the hen had set aside for her chick.

Everything in the plant world is directed to ensure that there will be a new generation to carry on life. We take advantage of many of the plant's provisions in order to maintain our life. If you consider these facts, and add others, in a thoughtful manner, you may learn a great deal about the scientific ordering of the existence of plants and animals, of how each of the races must provide for the future or perish.

D.D.T.

Even in school you can keep abreast of the great events happening in the outside world. Perhaps everyone would not think of the discovery of an extraordinary insect-killer as a 'great event'. I want you to watch during the next few years for the wonderful benefits which mankind may reap from a chemical now talked about as D.D.T. A high authority has declared that it is one of the greatest scientific discoveries made during the last ten years. It was first prepared in the Swiss laboratories of the firm of J. R. Geigy. It is a very complicated substance, having a chemical name thirty-one letters long. In 1939, the makers used it to save the potato crop of Switzerland from the Colorado beetle.

Its immense power to destroy vermin has been proved over and over again. The British Government adopted it in 1942, to keep its armies free from certain diseases carried by insects. Typhus is spread by lice, and malaria by mosquitoes. The ways in which the soldiers were protected, and epidemics in foreign countries checked, have now been made public. Deaths from typhus during and following world wars may run to many millions. In many countries teams of workers are at present investigating the action of D.D.T. against many hundreds of pests. The results are being stated with



Pest Control, Ltd.

FIG. 32. SPRAYING CROPS WITH D.D.T. FROM A HELICOPTER

great caution. Our interest here lies in its use in the garden. It has been proved to be decidedly effective against the Colorado beetle, cabbage caterpillars, cabbage root fly, carrot fly, and woodlice (Fig. 32). Proprietary preparations are now on the market, in some cases pyrethrum being combined with the D.D.T. Experiments may be made with them. Research workers are trying D.D.T. on all the garden pests.

GARDEN PRODUCE

The proceedings in the school garden should be considered with full reference to the work done in the cookery room. There should be arranged preliminary discussions among boys and girls about what ought to be grown in the garden with the view of its being cooked and eaten. The main arguments should be based upon the scientific values of foods, likes and dislikes taking a second place. Ways of disposing of the garden produce will enter into the talks, and there may be opportunities later in the year to criticize that produce by those who cook and eat it.

SCHOOL GARDEN AND FARM

Some of you no doubt live in farming districts, and you are sure to hear some talk about Young Farmers' Clubs. You may thus come to understand that the need for scientific knowledge in cultivating the land is widely recognized. Science rules the world nowadays. Your gardens and the farmer's fields are alike subject to the same principles of cultivation. The school and the farm should know each other well. Get interested in the big-scale problems. I will mention one, which is being widely discussed and thoroughly tested in practice; it is known as **ley** or **lea** farming.

It is based on a new rotation in the treatment of grassland. For four years the land is being grazed by bullocks; during that time the grass intermixed with clover is accumulating humus, and the ground is being manured by the dung of the animals. At the end of the four-year period the grass is ploughed in; the fertility thus stored up serves for three or four generations of crops such as turnips and oats. Then the ground is re-seeded with carefully selected plants, and returns to grass. Discussion of the merits and demerits of the scheme are to be found in several interesting books, some of which should be on your school shelves.

ROTATION OF CROPS

In a well-ordered school garden the ground will be worked on a three years' rotation plan. It is very well known that if the same crops are grown on the same ground year after year, the soil becomes 'crop-sick'. The main reasons for this are easy to understand, but no doubt there are various others of which we are ignorant. The first is that certain classes of plants take one particular substance from the soil in extra large proportions and leave the soil poor in it. The cabbage group, which demands much nitrogen, illustrates this. In the common rotation, cabbages would be followed by such crops as peas, beans and onions, and the ground would be manured for them with dung or compost. After those would come root crops, the storage organs of which require much potash, for example, potatoes, beet, carrot, parsnip. These would leave the soil poorer in potash, but not impoverished in nitrogen; it would thus be ready to support again the Brassicas. The area of the garden should be divided into three plots in order to carry out this succession, and a nine-spaced diagram would be drawn up on which would be set out details of the rotation of plants and the manures employed.

A second reason for moving crops from place to place is that certain crops are attacked by particular pests, that these breed in the ground around them and spend the winter there (p. 133), ready to make their attacks again in the next season. The cabbage fly and its maggots form a good example of this (p. 131).

MAKING RECORDS

Your work in the garden can be made to give you at least some of the training of the man of science. To secure this it must be something more than learning to do certain things and gathering up some useful knowledge. It must include most accurate observation of facts and happenings, and the keeping of exact records of them; these observations and records will form the basis for your reasoning from causes to effects, and for helping to solve problems. The gardener must also take into account the results of the work done by others and link up his own with these.

It follows that part of your gardening programme should consist of entering up in methodical form the history of the garden plants without a break, the methods and results of your experiments, and notes about anything which may have interested you as an individual. When a class begins its year's work it should have before it information about the treatment of the garden during the previous year, of the results of it, and of the conditions, particularly weather, which have affected these results. For the use of the class there should be such history tabulated on a large-scale sheet, on which are set out such details as dates of sowing or planting, special treatment, dates of ripening etc. A second sheet will give weather records. There will also be a plan of the garden on which are plotted the crops grown in the previous year, to be used in settling the rotation of crops. Material is thus at hand for the discussion of next year's use of the ground, and for considering failures and successes. It will soon become clear to you that gardening needs a great deal of thought and scientific knowledge.

MAKING EXPERIMENTS

You should use your reasoning power on every bit of work which you do in the garden, wondering why this should be done, and that should not be done, writing down all the questions to which you cannot find answers. All the time you should be seeking for truth; that means being a 'research worker'. If you do the work in this spirit, I should expect to find you inventing small experiments of your own. It would not be too ambitious for a school to take up some problem and make it a subject for school research—carried forward from year to year, if that were required. It would be a fine way of doing team work and handing on the torch to another team.

HORTICULTURAL RESEARCH

One of the most famous institutions in the world which carry on research in the cultivation of plants was founded a little more than a hundred years ago by a man who, when he was a school-boy, was always working out experiments which he devised himself. His name was John Bennett Lawes. John received none of his early education in chemistry through classes, but, as people sometimes say, he 'dabbled' in the subject. He carried on his hobby when he grew to be a young man; at first he used to do some of his experimenting in his bedroom, until he found a more convenient place in a barn.

Year after year he went on learning and trying out the ideas which came into his mind. Then he inherited an estate and was able to grow plants on a large scale for the purpose of experimenting on them with various chemicals in order to find out how they were affected. I believe the first of these experiments were made with bone manure (p. 75). Later on he became a manufacturer of superphosphate, a chemical which has done wonders in improving poor land. This was only one of many chemical fertilizers which he introduced into use. His projects expanded tremendously. His great achievement was the founding of a research station at Rothamsted, Harpenden, Herts., the oldest station of its kind in the world. It is now an immensely complicated institution, comprising about a dozen departments which deal with all the sciences involved in plant-rearing, attention being directed especially to the soil and its problems.

Research work on every subject connected with the cultivation of plants and the rearing of animals is now being carried on in many institutions in Great Britain—Cambridge, Oxford, London, East Malling, Aberdeen, and elsewhere. Another important and vigorous body is the Royal Horticultural Society. In their gardens and laboratories at Wisley, Surrey, many varied investigations are going on: they publish a most useful journal. A school might with advantage become a member of this Society. I mention these places with a special purpose in mind. Many men and women are employed in them in doing scientific work, and some of you readers might find there opportunity for interesting careers. Most other countries have similar research stations.

A Garden of Your Own

Your school garden will have been a failure, in my opinion, no matter how excellent a show its products may make, if it does not leave at least a good many of you with the determination to have gardens of your own some day. And even before 'some day' arrives I should expect you to have cajoled your father into letting you have a bit of the home plot in which to do your experimenting. Also, I hope you have grown so enthusiastic in your talk about your school garden doings that the parents have got interested as well, like to visit it, and, perhaps, help it along with gifts, as all real gardeners do to other gardeners.

Finally the day will come when you do your last bit of work in the school ground. You have worked in co-operation as class-mates: you have carried forward a little way the work done by those who toiled there before you; now you are about to hand over your spades to new hands. You ought to be able to think that you are leaving the garden in better condition than you found it.

CONCLUSION

VERY recently I read these words in a newspaper—'Sir John Boyd-Orr was the first man to take the oath to the United Nations as a *World Citizen*.' What do they mean? They have a meaning which concerns you and me and all of us. You ought to have heard of U.N.O. (United Nations Organization), the Organization composed of many nations of the world which set itself to help the world devastated by the Second World War to recover and to build up happier and more secure conditions of life in all countries. Sir John Boyd-Orr (now Lord Boyd-Orr), who was recognized as a great authority on nutrition and on the planning of food production on a national scale, was elected the first director-general of the Food and Agriculture Organization of U.N.O. He had previously directed the Rowett Research Institute in Aberdeenshire, and had run experimental farms; he was fitted to devote his genius to saving the world from famine or the fear of famine.

He and those associated with him set about their great mission without delay. On September 2, 1946, they opened a conference at Copenhagen; delegates from forty-two nations attended it. Sir John already had a comprehensive plan ready for discussion. His main idea was the creation of a permanent Food Council, which would control food production and distribution in such a way that no nation would be likely to suffer want. The whole world will wish success to such lofty ideals and bold planning; the whole world ought to do its share in furthering them.

I think that even the smallest of our country schools might be entitled to think of itself as one of the Director's team. If it has compelled its own patch of earth to yield the best of which it is capable, then it may rightfully claim a spot in the vast field which supplies mankind with food.

APPENDIX

ADDITIONAL EXPERIMENTS

(1) **Tests for nitrates.** Let the soil to be tested be dry and so arranged that water passes slowly through it. Take some of the filtrate in a test-tube and add to it ferrous sulphate solution. Then let a few drops of strong sulphuric acid slip down the side of the tube. If nitrate is present a brown ring will form where the two solutions meet; this ring will dis- disappear when the tube is shaken.

(2) **Test for protein.** Add strong nitric acid to the substance to be investigated and boil in a test-tube. The solution turns yellow. Allow it to cool and add strong ammonia; if the solution turns orange it is a sign that protein is present. The two solutions may be applied in drops to the cut surface of a broad bean seed.

(3) **Fehling's test for grape sugar.** For Fehling's solution: (*a*) Dissolve 35 gm. copper sulphate in 200 c.c. of water; (*b*) dissolve 70 gm. Rochelle salt in 200 c.c. of 10 per cent solution of caustic soda. Add first (*a*) and then (*b*) until deep blue solution is obtained. On heating, a deep orange precipitate is formed if grape sugar is present.

(4) **Test for cane sugar.** Boil the substance to be tested with dilute sulphuric or hydrochloric acid. This would change cane sugar into a mixture of

grape sugar and a sugar called laevulose which would show if Fehling's test were applied.

(5) **Test for starch.** Shake a little washing starch in warm water. Put a little of this into a glass of water, thus making a very dilute solution. Add to this a drop of solution of iodine (that is, a solution of iodine in potassium iodide). The starch solution will turn deep blue. A drop of the iodine solution applied to starchy substances (such as the cut surface of a potato tuber) makes a dark blue mark.

(6) **Testing wheaten flour.** Enclose some flour in a muslin bag; knead it in a basin of water for a little while. When the water has become milky, pour some of it off into a glass vessel. Then hold the bag in the water running from a tap until the water runs off clear of any milkiness. Within the bag is left a sticky mass of **gluten,** one of the proteins. Apply a drop of iodine solution to this lump; a yellowish spot appears; this forms a second test for protein. In time the water in the glass will become clear and a white sediment will collect at the bottom of the vessel. When this is tested with iodine it gives the starch reaction.

INDEX

A

Acids, 45
Air, necessary in soil, 49; plant breathes, 13
Alkalies, 46
Ammonia, 46
Anthers, 14
Annuals, 132
Aphides as carriers of virus, 113; on broad bean, 121
Apples, pollination of, 22
Artichoke, Jerusalem, 105

B

Bacteria, 58–63; as nitrate-builders, 61, 122; in leguminous plants, 122–4
Barometer, 144
Basil, sweet, 103
Bean, and bacteria, 122–4; broad, flower of, 17; germination of seeds, 91; cultivation of, 117; foodstuffs in, 101; French, 117, 119; scarlet runner, 117, 119
Bee, honey, 23–35; humble, 34; pollination by, 21
Beet, cultivation, 137; food value, 102
Beetle, 35; Colorado, 115
Bergamot, 103
Biennial, 132
Black fly, 121
Blight, 111
Bluebell plant, 138
Brassicas, 127
Broad bean, cultivation, 117; germination experiments, 4, 92–4; pollination, 18; seeds and seedlings, 93
Bulbs, 138
Butterfly, 34, 35; life-history, 130

C

Cabbage, family, 127–31; food value, 102; moth, 130; seedlings, 128; root-fly, 131
Calcium manures, 76
Calyx, 14
Carbon, 12; dioxide; 13
Carbohydrates, 12
Carpels, 20
Carrot, cultivation, 132; fly, 132, 135; food value, 102
Cells of leaf, 12
Chalk manure, 77
Chervil, 103
Chile saltpetre, 74
Chives, 103
Chlorophyll, 11
Choice of plants, 99–104
Clay soil, 39, 42
Climbing plants, 119
Cloches, 52, 96
Clover and bees, 33
Club root, 131
Colloids, 41
Colorado beetle, 115
Compost heap, 58, 71
Corm, 156
Corolla, 14
Cotyledons, 95

Crocus corm, 156
Cross-pollination, 20
Culture solutions, 80

D

Dicotyledons, 140
D.D.T., 131, 158
Digging, 65

E

Earthworm, 55–57
Elements in plant food, 60
Embryo, 18, 93
Experiments, making, 163

F

Farm, 160
Fats, 12, 99
Feeding, plants, 156; the soil, 68–78
Fertilization, 15; nature of, 18, 19, 20; self, 20
Finger and toe disease, 131
Flies, 34
Fly, black, 121; carrot, 132–5; root, 131
Flower, parts of, 14
Food, plant, 68; storage, 157
Foodstuffs in vegetables, 101
Frost, effects on plants, 142; effects on soil, 53

G

Germination, 91
Gluten, 170
Green colouring matter, 11
Green-fly, 113, 121
Green manuring, 45, 73
Gromore, 77

H

Herbs, 102
Honey, 32
Honey bee, 23–35
Hop manure, 72
Humble bee, 34
Humus, 38

I

Inorganic matter, 46
Insect, structure of, 23
Insect and flower, 16–22

J

Jerusalem artichoke, 105

L

Larvae, 29, 130
Lavender, 104
Leaf structure, 12
Leaves as manure, 72; seed, 95
Leeks, 137, 139
Leguminous plants, 117–26
Light, necessary for chlorophyll, 11; retards stem growth, 107, 120
Lime, character of, 77; presence of, 47; test for, 77; use of, 76
Liquid manure, 73, 154
Loam, 39

M

Maggots, 131
Manures, kinds of, 70–8; liquid, 154
Manuring, green, 45
Micropyle, 91
Mineral salts, 100
Mint, 103
Monocotyledons, 140
Moths, 35; life-history, 130
Mulching, 148

N

Nectar, 17, 32; and the bee, 30
Neutral soils, 47
Nitrates and bacteria, 60–2; test for, 169
Nitrogenous manures, 74
Nodules, root, 122

O

Oils, 99
Onion, cultivation, 137; food value, 102; fly, 140; germination, 140
Organic matter, 46
Ovary, 14
Ovule, 14

P

Parsley, 103
Parsnip, cultivation, 136; food value, 102
Peas, cultivation, 117; food value, 101
Peat manure, 72
Peoples of the soil, 55–63
Petal, 14
Phosphate manures, 75
Plant structure, 3–15
Pollen, 14; bee gathering, 27
Pollination, 15; nature of, 18, 19; cross, 20; by bees, 21
Potato, 115–16; blight, 111; cultivation, 107; disease, 107; food content, 101; scab, 111; seed, 114; sets, 106; tuber, 106; virus, 112
Potash manures, 75
Protein, 12, 99; test, 100, 169
Protozoa, 58
Pupa, 29, 130

R

Rain gauge, 147
Records, 162
Research, horticultural, 164
Rhizomes, 103, 152
Root-fly, 131
Root hairs, structure and function, 4, 8, 42
Roots, nature of, 3–7
Rosemary, 104
Rotation of crops, 125, 161
Rothamsted, 164
Runners, 152

S

Sage, 103
Salad vegetables, food value, 102
Salt, 137, 155
Saltpetre, 74
Sandy soil, 39, 42
Savory, summer, 103
Scarlet runners, 117, 119; dwarf, 120
Seed, 91; beds, 95; leaves, 95; sowing, 95
Seedlings, rearing, 98; transplanting, 98
Self-fertilization, 20
Sepal, 14
Shallot, 139

Sets, 3
Shoot, nature of, 8
Slugs, 129
Snails, 129
Sodium chloride, 155
Soil, alluvial, 38; chemical properties, 45; garden, 36–48; types, 39
Soot, 73, 74, 134
Sorrel, 103
Stamens, 14
Starch, 12, 99; test for, 170
Stigma, 14
Stomata, 10
Storage of food in plants, 157
Structure of plant, 3–15
Style, 14
Subsoil, 37
Sugars, 12, 99; tests for, 169
Summer savory, 103
Surface tension, 40
Sweet Basil, 103

T

Tarragon, 103
Temperature of soil, 49–54; and seed-sowing, 52
Tendrils, 102
Thermometer, 146
Thinning seedlings, 152
Thrips, 121
Thyme, 103
Transpiration, 11
Transplanting, 5, 98
Trenching, 67
Tubers, 105
Turnip, cultivation, 135; food value, 102; flea-beetle, 136; fly, 135

V

Veins, 8
Virus diseases, 112, 113
Vitamins, 100

W

Wallflower plant, 3–15
Water, 100; absorption by root-hairs, 4; conditions in soil, 40; entry into plant, 40, 42; movement within plant, 8–11; supply from various soils, 42
Water culture experiment, 79–80
Watering, 150
Weather, 141; records, 144
Weeding, 150
Weevil, 122
Wheaten flour, 170
Winds, effects of cold on plants, 143
Wireworms, 57
Wisley Gardens, 165
Wood ash, 71, 76; use of, 136, 137

PRINTED BY PURNELL AND SONS, LTD.
PAULTON (SOMERSET) AND LONDON